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Demand Better

The same interventions that have set electricity generation and personal vehicles on a path to zero emissions can enlist corporate net-zero ambitions to do the same for everything else.

Here's how.

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Introduction

Burning fossil fuels generates more than 80% of global greenhouse gas emissions. With few exceptions, it is technologically viable to replace fossil fuels with electricity from renewable sources. Transportation, heating and cooling, industrial heat, and chemical reactions are all amenable to electrification at a scale that can largely decarbonize much of our economic activity. If there is a way to sustain our collective, technologically advanced civilization with a net-zero footprint, giving up carbon bonds for electrons is going to be a large part of the answer.[1] Electrification is a double-edged sword, however: unless we can simultaneously decarbonize the production of the commodities and infrastructure required for this transition, our efforts are at risk of being self-defeating.[2]

A dramatic increase in the use of electricity will require a similarly dramatic increase in the production of entire classes of commodities and manufactured products. Standing up sufficient green generating capacity on the relevant time scale requires more solar panels and wind turbines. Distributing all that new power will require more pylons and transmission wires. Expanding storage infrastructure means lots of new batteries and other solutions. Consuming that power requires more electric vehicles (EVs), heat pumps, induction furnaces and cooktops, and other new consumer and industrial equipment. Manufacturing all this implies significant increases in the production of base, precious, and rare earth metals and minerals, and new smelting and refining capacity for iron and steel, manufactured metal products, cement and construction materials, plastics, chemicals, and so on.

These indispensable ingredients of electrification are currently carbon-intensive to produce and resistant to decarbonization efforts; indeed, they are known, collectively, as “hard-to-abate” (HTA) commodities. Perhaps surprisingly, the decarbonization challenges they pose are not primarily, or even mostly, technical. Well-understood technologies combined with innovative process redesign can dramatically reduce the carbon intensity of many HTAs. Perhaps predictably, however, lower carbon production typically implies higher costs, at least initially, that, too often, too few customers are willing to pay.

For example, steel producers could cut their direct emissions by 80% or more, but the cost increases overwhelm the industries’ margins, so producers cannot simply absorb the increase. Neither can they pass the cost on to their direct customers, since steel is typically a major cost element for them—and so they, too, cannot simply take the hit, nor can they often enough pass along the cost. As a result, few steel producers are investing in low carbon production alternatives at meaningful scale, and almost all steel production remains carbon-intensive, for solely economic reasons.[3]

At the same time, many HTA commodities require “long lead time, long lifetime” investments. To meet anticipated future demand arising from increasingly rapid and widespread electrification, many HTA commodity producers are planning today for production that will come online a decade or more hence. Consequently, we—the economies, countries, and companies attempting to drive sustainability, globally—are in grave danger of undermining our own efforts by locking in decades of high-carbon production of the inputs needed for decarbonization.[4]

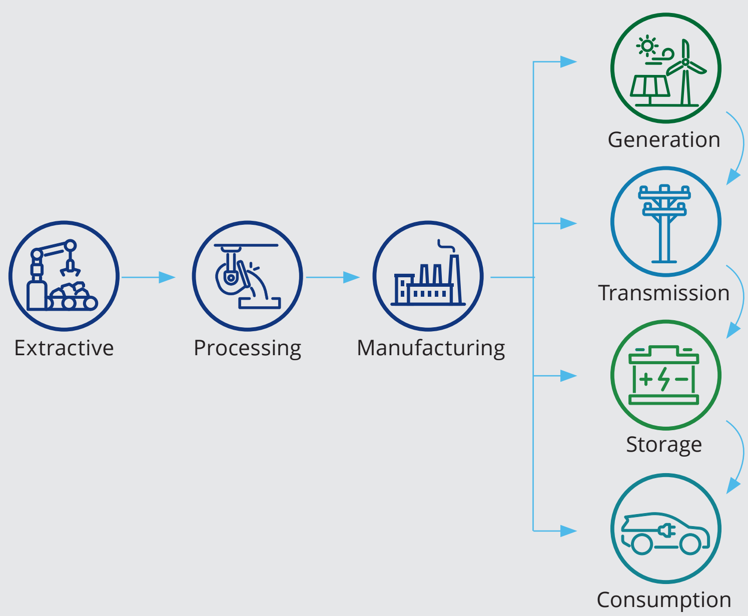
If we're not careful, the best-case scenario might be no better than an embrace of, say, EVs and heat pumps in consumer and commercial markets, leading to a dramatic decrease in "tailpipe" emissions, but a dramatic increase in "smokestack" emissions from the mining, refining, and manufacturing needed to provide the infrastructure and products that electrification requires. That's two steps ahead and one step back, when what is needed is a giant leap forward. In other words, these hard-to-abate sectors are also "we-can't-wait" sectors.[5]

True: there are green versions of some currently carbon-intensive inputs, such as steel. But the markets for these products tend to be small, typically limited to the price-insensitive segments of a few high-margin markets such as luxury automobiles. This limits opportunities for the kind of growth that can drive rapid cost reduction and at-scale deployment.[6]

That makes significant progress slow and uncertain, and that's not okay. If the global economy is to reach net-zero within a time frame relevant to human survival, never mind flourishing, we should decarbonize the HTA sectors in industrial markets at least as fast as we electrify consumer markets. That means we should demand better of the producers and consumers of HTA commodities, of the standard-setters that shape the market for carbon abatement, and of ourselves.

Figure 1: Power arrangers

Abandoning fossil fuels for electricity for most energy needs implies a dramatic increase in renewable generation capacity, enhanced and extended transmission infrastructure, creating entirely new and substantial energy storage capacity, and replacing cars, appliances, and heating devices. All this new infrastructure and machinery will require significant new quantities of metals, plastics, concrete, and other essential inputs.



Source: Deloitte analysis

It's electric

The challenge of decarbonizing the production of HTA commodities is not unprecedented. For example, electricity production was long the largest contributor to US-generated greenhouse gas emissions, but thanks to the deployment of zero-carbon sources, primarily solar and wind, it has recently fallen to second place, behind transportation. Renewable sources of power, which were once orders of magnitude more expensive than energy from fossil fuels, are now typically significantly cheaper, and now account for more newly-installed capacity than coal or gas.[7]

How did renewables come down their cost curve? After all, technologies don't get cheaper by magic: it typically takes investment, first in innovation and learning, and then in large-scale deployment, to drive down costs sufficiently to reach mass market adoption. But if you can't sell your product because it's too expensive, and can't make it cheaper until you sell it, how does anything new ever succeed?[8]

A solution often lies in connecting with a market segment willing to pay more for a differentiating attribute of the novel technology. For example, when mobile telephony was introduced in the 1980s, it cost much more than incumbent landline solutions, was far less reliable, and had patchy coverage. Expensive, poor connectivity, and limited range—not exactly a compelling value proposition![9]

Luckily, a small—but still large enough—segment was willing to pay those high prices and tolerate other seeming shortcomings to enjoy the convenience of mobile voice communications. Revenue from these early adopters justified focused investments by network operators in major cities and along high-density corridors. As increasing numbers of customers realized the true utility of being untethered, network providers saw more clearly the business case for increased innovation and the large-scale deployment of mobile technology.

In the early days of renewable energy generation, however, this path to market penetration was largely closed off. With mobile telephony—or VCRs, personal computers, gaming consoles, and so on—only those customers willing and able to pay for the new technology bore the cost. But with electricity, it is impossible to "track the electrons," so utilities typically charge their customers based on their average cost of power generation. Adding renewables to the mix meant everyone had to pay for the higher-cost technology, not just those customers that were willing to.

Utilities were stuck. Deploying renewables unfairly burdened some—in fact, most—customers, but not deploying renewables denied others. The market had failed: transactions that buyers and sellers wanted to execute were thwarted due to an inability to connect supply and demand.

Real power, virtual purchase

Part of the solution lay in government subsidies, which reduced the cost burden on utilities and customers.[10] In addition, essential incremental demand—and, critically, a line of sight to revenue—was crystallized through virtual power purchase agreements (VPPAs). These financial instruments allow buyers to purchase electricity separately from its environmental attributes—in this case, the carbon footprint of generation.[11]

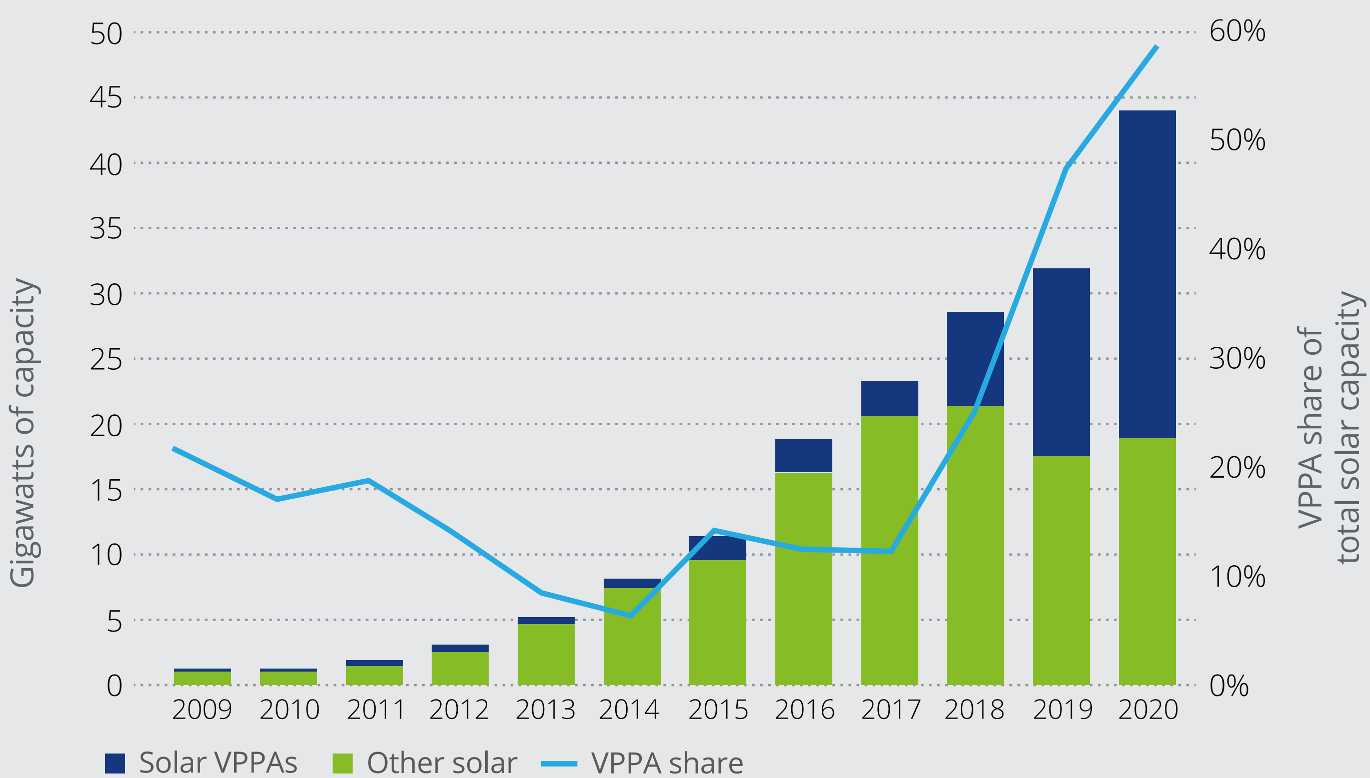
For example, imagine that the cost of zero-carbon electricity is $0.15 per killowatt-hour (kWh), and the cost of coal-fired power is $0.05 per kWh. A company that wants to virtually purchase green power would guarantee the green provider a price of $0.15 per kWh for, say, 100 kWh in a month. Over the course of the month, the green power provider would generate and dispatch 100 kWh of zero-carbon electricity, selling it at the market price, which might fluctuate between, say, $0.04 and $0.25 per kWh. At the end of the month, the company that purchased the VPPA pays the generator the difference between the realized revenue and the guaranteed revenue. If the minimum efficient scale of green power generation is greater than the needs of a single customer (which is often the case), VPPAs with a number of consumers can be aggregated to support a single renewable project, thereby providing the requisite total demand. In this way, the buyers of green power collectively assume the market risk associated with deploying renewable generation technology, enabling the production of more green power than would otherwise have been possible.[12]

In this transaction, the power is real, but the purchase is virtual, since there is no necessary connection between the green power produced and the power consumed by the VPPA holder. The green power is generated, dispatched, and consumed by someone, displacing power that would have otherwise been generated by fossil fuels, and so the VPPA has advanced the desired system-level change.

In other words, even if the company paying for green power is consuming electricity from a coal-fired generator, it has, thanks to the VPPA, still contributed to the decarbonization of electricity generation to an extent commensurate with its use. That's why major standard-setters have recognized VPPAs as a credible way for companies to "zero out" their electricity-related, or "scope 2" carbon emissions, making VPPAs an often-indispensable component of most companies' corporate net-zero strategy.

Today, the cost of new installations of renewable electricity is typically lower than new fossil fuel-based generation. Even so, VPPAs still have an important role to play, since we must now justify decommissioning existing “dirty” capacity, and clearing that hurdle can often require revenue subsidies. In addition, there often remains a mismatch between the location of renewable capacity and those companies wanting to ensure they are supporting the continued deployment of renewable generation. It is, in part, for these reasons that the VPPA market remains vibrant and growing.

Figure 2: The sun always shines on VP



Source: Allied Market Research (2023); Kobus et al. (2021); Deloitte analysis

Cut and paste

The HTA market would appear to suffer from the same impediments that once plagued renewable energy. For example, hydrogen is an important chemical feedstock that is, today, most often produced using methane, generating significant greenhouse gas emissions. Hydrogen produced with electricity from renewable sources has zero greenhouse gas emissions. Unfortunately, green hydrogen costs three to five times as much as so-called grey hydrogen.[13]

This price premium is likely much of the reason that green hydrogen accounts for less than 1% of the total, with applications limited to high-end segments. For example, an automobile manufacturer might believe customers of its luxury models will pay the necessary price premium for a car with a lower-carbon manufacturing footprint. It therefore procures green steel, which in turn relies on iron ore that has been processed using green hydrogen.

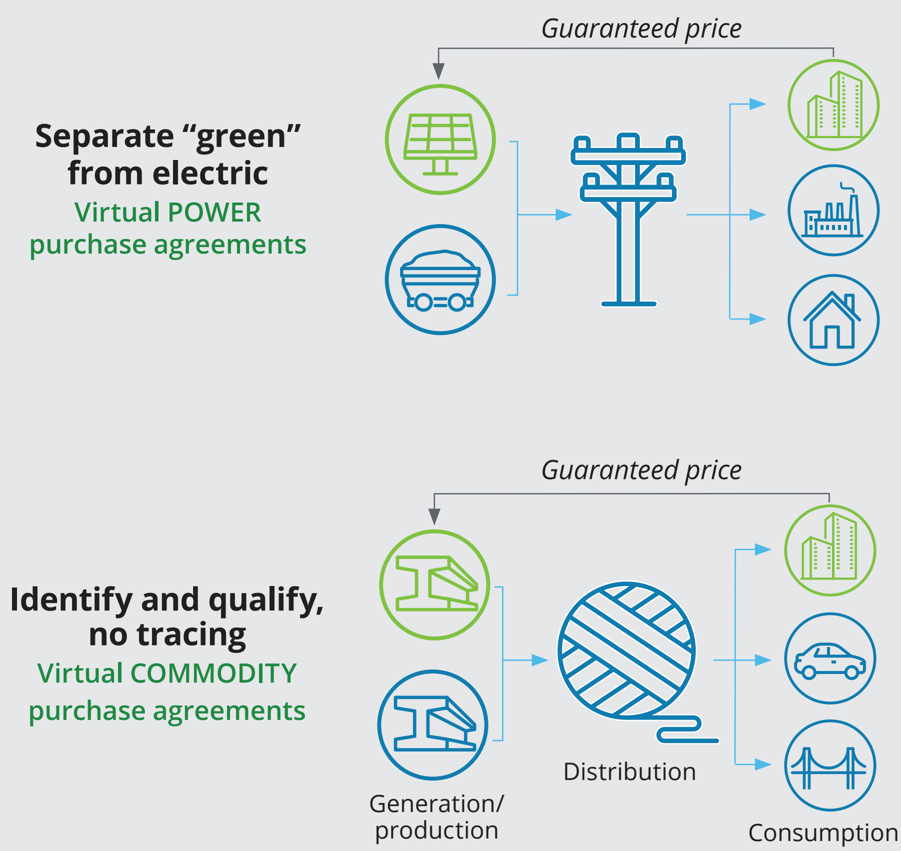
The automaker's marketing claim depends on a direct value chain connection from green hydrogen to luxury sedan, and that lower carbon steel inputs reduce the total carbon footprint of the car by enough to matter to customers. A potentially big bump in the price of a major cost element means the price premium on the final car is likely to be significant in an already high-priced segment. That means the demand for green hydrogen depends on the volume of steel required in the nichiest of auto market niches. That goes a long way to explain why green hydrogen volumes are low, progress is slow, and success is uncertain.[14] Conceptually, at least, VPPAs could be adapted to lubricate this market—and perhaps the market for almost any HTA commodity; call these VC(ommodity) PAs. Just as electricity is untraceable thanks to the commingling of power from different generation sources in the distribution grid, many HTA commodities (e.g., metals and agricultural products) are similarly commingled in the distribution process, making it impractical to trace those inputs to their original sources.[15]

As with VPPAs, VCPAs could separate a commodity from its environmental attributes. Those companies willing to pay the necessary premium for green versions of HTA inputs need not actually consume the green commodity. Instead, they would simply guarantee a price to producers of green commodities. When that green production is sold, the company that purchased the VCPA can claim credit for having displaced a similar quantity of carbon-intensive production.

This would allow our automaker to source the "green" in its steel, and the steelmaker to source the "green" in its hydrogen, from anywhere, virtually, while purchasing actual inputs from current providers, thereby relieving the constraints of physical supply chain connections. It would also facilitate volume aggregation across those price-insensitive customer segments for any consumer product with sufficient HTA commodity content, increasing total demand.

Figure 3: Without a trace

Many companies have reduced their implicit emissions from the purchase of electricity (scope 2) with VPPAs. Companies know that they consume electricity, and they know how much, they just don't know which electrons fed their needs. Adapting VPPAs to other commodities is conceptually straight-forward, but requires a way to identify which commodities a company requires, and how much of each ... even though there is no practical way to measure these parameters directly, thanks to the complexity and dynamism of modern supply chains.



Source: Deloitte analysis

Not quite enough

Swapping out electricity for steel or concrete as the commodity that is purchased virtually would be a great start but is unlikely to be enough, because HTA sectors lack two essential features that made the electricity market amenable to a virtual purchase solution.

First, for most installations, the price of the marginal solar panel or wind turbine is, practically speaking, largely constant. In addition, the quantum of incremental capacity is very small—at the limit, a single solar panel or wind turbine. That allowed energy providers to calibrate green generation capacity to the size of the market segment willing to pay whatever the higher price for zero-carbon electricity was at that time. If there was call for only 100 megawatt-hours of high-cost green power, then producers could install precisely that much capacity with no material cost implications. In other words, supply could match demand.

Second, practically everyone buys electricity. That means the target market for VPPAs is anyone the VPPA seller wants to sell to. With a target market of the entire economy, there is a pretty good chance that someone, somewhere, will bite at almost any price.[16]

In short, the VPPA market had maximum supply flexibility and the largest practical total addressable market. And even so it has taken nearly 40 years for these instruments to evolve to the point that they are material contributors to the ongoing deployment of green power generation.

In contrast, the radical decarbonization of many HTA commodities tends to require much larger and lumpier fixed cost investments. If an 80% decarbonized copper mine is going to sell its output for less than the price of gold, it might need volume guarantees of many tens of thousands of tonnes per year, with incremental cost reductions from scale requiring similar quantum increases in output. In other words, demand has to match supply.

To binding supply constraints add a limited direct market. The value proposition to buyers of low-carbon inputs is that the resulting products will, in turn, be low carbon and that their customers will be willing to pay more as well. That implies a significant fraction of the final product's input needs to be the decarbonized commodity. So, steel with a lower carbon intensity might be likelier to find a market when it is included in a product that requires a lot of steel. However, this will tend to limit producers of green steel to selling to makers of high-end cars and appliances. Worse, it's not clear which consumer markets would support the decarbonization of concrete, aluminum, rare earth metals, drywall, organic chemicals, and so on. Although these inputs are essential to a modern economy and, collectively, account for the lion's share of the economy's total emissions, they are often both invisible to consumers and a small fraction of the inputs to a given end-use product. Consider, for example, the relatively minute, but essential, quantities of copper and other mining commodities in a computer or mobile phone.

It's plausible that VCPAs could help, since relaxing the requirement of a direct supply chain link and aggregating what demand there is can only be beneficial. But just as likely is that the need for large purchase commitments in lumpy increments from small, fragmented markets will leave us with only small-scale, slow, stuttering progress toward the decarbonization we so desperately need.

The scope 3 solution

The bad news is there is no readily apparent way to give the HTA sectors the supply flexibility that renewable energy enjoys. Engineering constraints make relatively large, lumpy investments for most HTA commodities unavoidable, at least for now.

The good news is that we can mobilize the corporate net-zero movement to provide critical incremental demand for decarbonized HTA commodities. By connecting every corporation's implied demand for HTA commodities to their carbon footprints, companies can reach a credible net-zero status by funding the decarbonization of the commodities that ultimately drive their carbon footprint, but that they don't purchase directly.

For example, a car maker's need for steel is intuitive and practically straightforward to identify and quantify, which is why a car maker can credibly claim that it has a "low-carbon car" if it uses low-carbon steel.

But the number of direct purchasers of steel in no way captures the number of companies that ultimately use steel. For example, a consulting firm doesn't buy steel or concrete or copper in order to deliver consulting services, yet its economic activity is what justifies the production of these inputs in the first place. After all, no one makes structural steel or industrial concrete as a hobby. Rather, it's because consulting firms are leasing space in office towers and staying in hotels that there is incremental demand for commercial space and so, eventually, a reason to make steel girders and concrete to construct new buildings. Similarly, flying on planes creates demand for aluminum, leasing computers creates demand for copper, and so on.

Unlike our auto example, however, it is, as a practical matter, impossible to determine precisely how much of which upstream HTA commodities are produced in response to the indirect demand created by, say, consulting firms, law firms, movie studios—let's just say "downstream" commodities. Modern supply chains are simply too complex and dynamic to capture the recursive linkages among not just the copper embedded in the laptop computer, but also the copper in the wiring of the electrical infrastructure that powered the chip fab that made the microprocessor in the computer.

There is a credible workaround. The Bureau of Economic Analysis (BEA), an agency of the US Department of Commerce, uses data on intra- and inter-industry trade to estimate the "bill of materials" for everything the US economy produces. That is, the BEA specifies how much of each of the 411 commodities it recognizes is needed to produce $1 of each of those same 411 commodities. For example, according to BEA estimates, in the United States it takes $0.01 of legal services to produce $1 of consulting services, and $0.003 of consulting services to produce $1 of legal services; and, to complete the grid, legal services are also an input to legal services ($0.009/$) and consulting is an input to consulting ($0.02/$).

Figure 4: In 'n out

To produce $1 of outputs

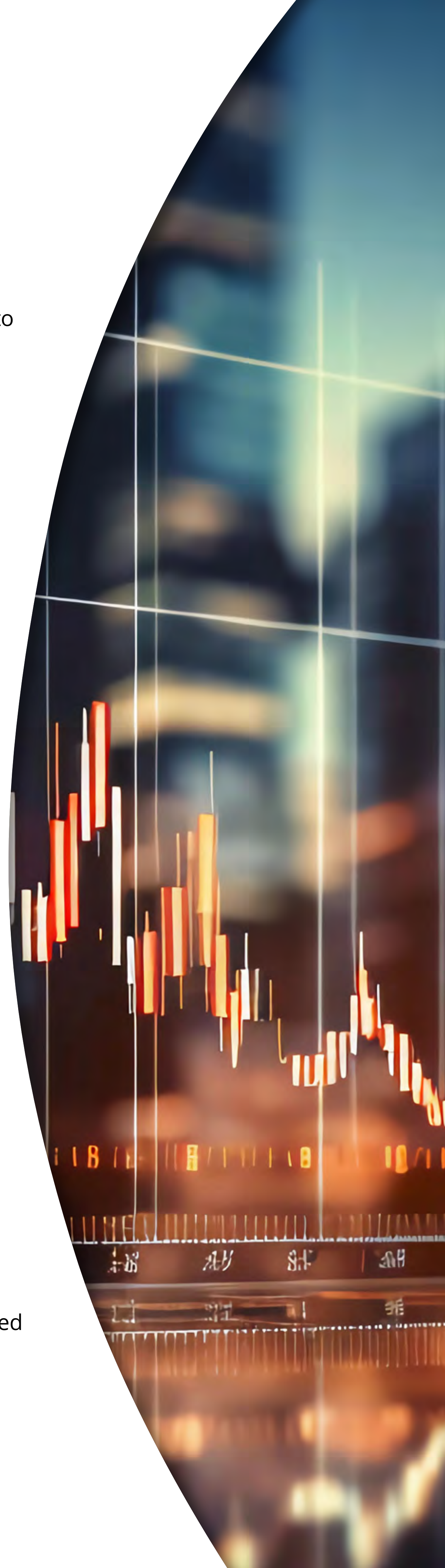
It takes $X of inputs		Legal	Consulting
	Legal	$0.009	$0.01
	Consulting	$0.003	$0.02

The supply, or value chain metaphor, with upstream and downstream elements, can be very useful, but in the context of decarbonization, it can also be simplistic to the point of misleading. Every output of the economy is also an input to something elsewhere in the economy—after all, if no one wanted to buy it as an input, it wouldn't be produced in the first place. Less obviously, the production of most outputs requires at least some of just about everything somewhere in its value chain. Consequently, the economy is not a series of semi-isolated "chains" but a single, integrated loop. The input–output tables quantify these interdependencies for everything produced and consumed by an economy. This table captures the relationship between two commodities—legal services and consulting. The US input–output table does the same for everything produced by the US economy.

Source: Deloitte analysis; EEIO tables

Expand this 2x2 matrix to 411x411 and you have the direct requirements (DR) table for the US economy. Using some fancy-pants matrix algebra (the development of which earned Wassily Leontief the Nobel prize in economics in 1973), the BEA then calculates the total requirements (TR) table. These figures capture how much of each input is required across the entire economy to produce $1 of every commodity.[17]

These estimates have long been the foundation of the Greenhouse Gas Protocol (GHGP) guidance to companies on how to estimate their upstream, or supply chain, scope 3 carbon inventory. For example, the US Environmental Protection Agency's (EPA) spend-based emission factor (EF) for legal services is 0.08 kilograms of carbon dioxide equivalent per dollar (kg CO_2e/$).



A company that spends $1 million on legal services might use that EF to estimate a scope 3 burden from legal services of 80,000 kg.

Now things get interesting. Recall: the challenge is figuring out how much, say, steel is produced in response to the ultimate demand created by, say, a consulting firm's economic activity. Perhaps somewhat surprisingly, an answer to that question lies in how the emission factor for legal services is derived. Specifically, estimating the carbon footprint arising from the delivery of legal services—or anything else, for that matter—depends upon estimates of the TR of legal services for the inputs it, in turn, requires.

For example, although the DR of legal services for grain is $0 per dollar (implying that the law firms buy essentially no grain—not a surprise), legal services has a TR for grain of $0.0005 per dollar, thanks to the cumulative needs of all the upstream inputs that, eventually, legal services does buy. To illustrate, this might arise from law firm associates staying in hotels that purchase restaurant services that buy baked goods that use grain. The TR estimate for legal services' need for grain ($0.0005/$) is then multiplied by the direct (scope 1) carbon emissions associated with the production of that commodity and added to the EF for legal services. In short, the estimated emissions associated with delivering $1 of legal services is based, not on what legal services purchases, but on what legal services uses. Current practice adds those upstream scope 1 emissions to generate a given input's supply chain (upstream scope 3) inventory.

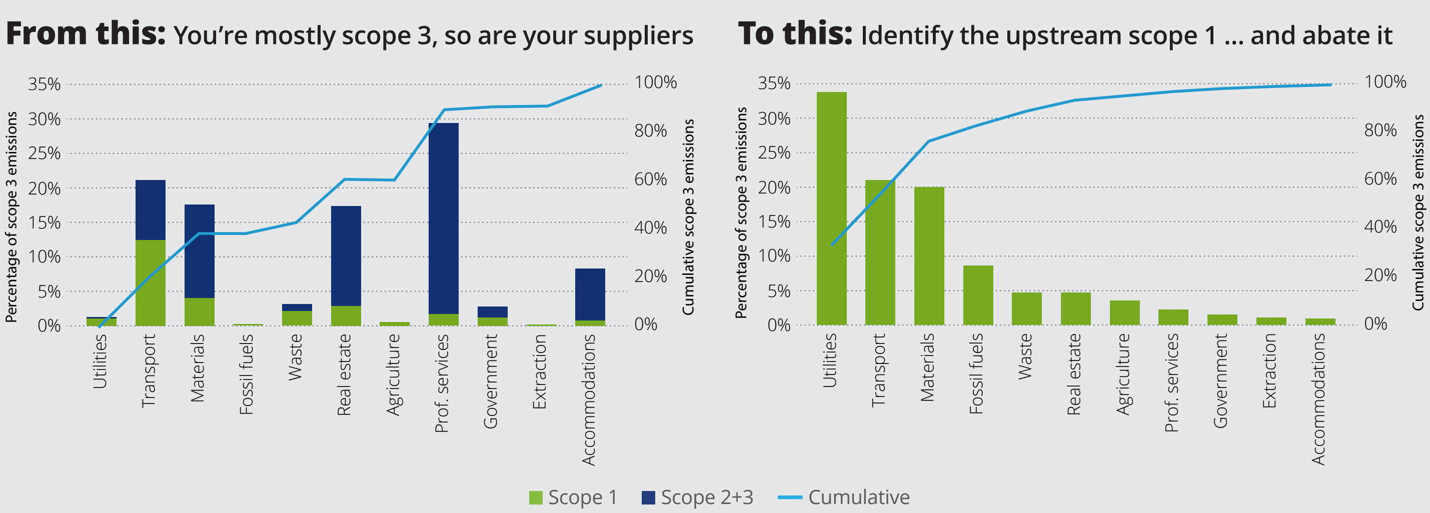
Perversely, this makes it much harder for the company purchasing legal services to reach the 90% reduction in emissions required for net-zero. For example, a company wanting to reduce the 80,000 kg in its supply chain carbon burden arising from purchasing $1 million in legal services will find that legal services don't generate much carbon directly, and 90% or more of the carbon from legal services is generated by legal services' own supply chain.

That is, it's not the legal services generating the emissions; it's other upstream sources of scope 1 that accumulate along the supply chain to become legal services' scope 3. And the only way to get rid of legal services' scope 3 is to find that upstream scope 1, from indirect inputs such as grain (which has a direct impact factor of 1.7 kg CO_2e/$ and is less than 30% scope 3), and then eliminate that.

Since the emissions burden for legal services is calculated using TR-based estimates of the commodities generating the relevant scope 1 emissions, we already have good enough information to take meaningful action. The TR table tells us that $1 million in legal services relies on $145 of copper, $1,410 of steel, $108 of drywall, and so on. To repeat: legal services doesn't buy any of those things directly; and, as a practical matter, it's impossible to find the specific copper ore, steel beams, or sheets of drywall that were actually consumed by identifiable upstream suppliers to support a legal firm's particular day in court. Rather, these figures are what one would expect, on average, to be consumed throughout the entire economy to support the provision of legal services, generally. And therefore, our most direct route to eliminating the scope 3 from legal services, and reducing the passed-along scope 3 emissions from purchasing legal services, is to eliminate the scope 1 emissions arising from the production of the relevant quantity of the relevant commodities.

And with a minor twist of the VPPA/VCPA model, we can do precisely that.

Figure 5: Show me the scope 1



Most companies estimate the total emissions generated by the inputs they purchase directly to quantify and manage their scope 3 burden. For consulting, this implies that Professional Services is the largest contributor, accounting for nearly 30% of the total scope 3 inventory. However, note that Professional Services is more than 90% scope 3 itself, which means that the ultimate sources of the emissions lie still farther upstream.

Every scope 3 inventory can be recast in terms of the scope 1 emissions associated with the production of the relevant quantities of the relevant upstream commodities. Although the total scope 3 burden is unchanged, the drivers of those emissions are seen very differently. For our hypothetical consulting company, Professional Services falls from 30% to 2% of the total. Materials has a similar level of significance (15%–20%), but now the focus is on abating directly controllable upstream scope 1. And Agriculture and Extraction rise from meaningless to the difference between *hitting net-zero or not.*

Source: Deloitte analysis; EEIO tables

Advance, indirect, and contingent

VPPAs and the (for now) hypothetical VCPAs described above solve the structural "horizontal" supply chain problem. That is, an automaker wanting to "go green" by purchasing green power and green steel might find that its direct suppliers in its actual supply chain cannot provide green inputs at tolerable costs, while other suppliers of the same commodities can—but their customers can't or don't want to pay. The automaker would prefer to shift "horizontally"—that is, within the same tier of its supply chain—to the green supplier, but the additional costs for, say, transport or trade duties, make such a shift impossible. Thanks to VCPAs, the automaker can make that shift "virtually" by purchasing the "green" component of its inputs from the green suppliers, and so decarbonize the relevant commodities in the relevant quantities, even as it purchases the actual commodities from its existing supplier base.

Most companies, however, have a scope 3 problem that is vastly more complex than our automaker example. A consulting company, for instance, might find that its inventory is 90% upstream scope 3, but that its suppliers are all 90% upstream scope 3 too—and for reasons already discussed: consulting firms don't buy copper, they buy legal services; and legal services don't buy copper either, they buy financial services, and so on.

For most companies, then, a virtual horizontal shift in the supply chain is of little use. What they need is a virtual vertical solution—a way to reach through their impenetrably dense, complex, opaque, and dynamic supply chain and eliminate the upstream scope 1 emissions that roll up, eventually, to become their scope 3. With a VPPA, the commodity being decarbonized (electricity) is purchased by the company directly. For most other commodities, what is being decarbonized is purchased on its behalf, indirectly, by the company's suppliers, or their suppliers' suppliers, and so on, making a VCPA for far-upstream commodities "indirect."

Furthermore, for many of the commodities in question, there is no existing supply to subsidize. Before mining companies will make the investments needed to produce near zero-carbon copper, they need to believe that they will be able to sell their production at the necessary price premiums. Consequently, companies committing to, say, copper VCPAs would be making promises of future payments that would, in turn, give the relevant mining company the confidence required to invest in a mine built around completely different technologies and mine design principles.

It could easily take five to 10 years before the low-carbon copper is delivered—and only then would the copper VCPA purchaser have to make good on their obligation, and even then, they would be required to pay only if the mining company delivered the agreed-upon quantity at the agreed-upon level of carbon intensity.

VPPAs, then, are current, direct, definite purchases. VCPAs, as described here, are advance, indirect, contingent purchases.

Innovation, learning, and scale

How much support might, say, zero-carbon concrete require, and for how long, before a full-scale, self-supporting transition to low-carbon technologies and processes were underway? Perhaps far less than one might think. Recall that VPPAs made a measurable contribution to the rise of renewable electricity generation despite subsidizing, at first, a small fraction of total electricity production. A second and higher-contrast example of how little it can take to transform an industry is the consumer automotive market, which was set on a path to full electrification by a single company that had, at the time, a market share of a fraction of one percent.[18]

Since its founding in 2003, Tesla's vision has been to create a mass-market all-electric vehicle. By 2006, supported by just over US$100 million in private financing, the Roadster was made available for pre-order, requiring a US$100,000 deposit. The first models hit the Southern California roads in 2008. Based on a Lotus Elise chassis, and with a 0–60 mph time of just over four seconds, the car was stylish and fast—but took 24 hours to charge, had a range of less than 250 miles, and, in 2009, had to issue a recall on almost 350 Roadsters out of a cumulative production of fewer than 2,000 units.

Even so, by 2010, major automakers seemed intrigued: Daimler and Toyota each purchased $50 million stakes, and the company went public shortly thereafter. A year later, the Model S, a luxury sedan almost as fast as the Roadster and with 50% greater range, debuted in limited release. In 2012, the company began rolling out its proprietary high-speed charging infrastructure together with the full-scale launch of the Model S.

In 2014, the company shipped 31,655 cars into a North American and European car market of nearly 30 million vehicles, giving Tesla a market share of around 0.1%. Yet that was enough to justify the announcement of the so-called Gigafactory, Tesla's large-scale battery manufacturing facility that would support the 2017 launch of the Model 3, Tesla's mass-market EV. In 2020, Tesla was profitable over a full fiscal year for the first time and became part of the S&P 500.

Although Tesla is no longer the world's largest EV maker (China's BYD recently usurped that crown), the company's catalyzing impact on the industry is difficult to overstate.[19] Governments around the world are implementing ICE phase-out policies, many culminating in the outright banning of the sale of new ICE vehicles—some as early as 2025.[20] And in the last two years, more than 20 major automakers accounting for almost 70% of global production have committed to stop making internal combustion engine (ICE) automobiles—some as early as 2030, but all before the critical net-zero year of 2050. One can only wonder whether the timing and nature of these commitments was informed by Tesla's success, which demonstrated the technical and economic viability of electric vehicles.[21]

In other words, the auto market tipped to EVs long before EVs accounted for a dominant share of the industry's annual sales, never mind a dominant share of the installed base. Effectively, the entire global auto sector is racing to catch the EV wave, and the market forces that once held back EVs are now accelerating their adoption.

A little means a lot

This potted history reveals a key characteristic of market transformations that suggests VCPAs can drive significant change. Specifically, markets can tip long before an innovative solution captures significant market share. Alternative approaches need not necessarily capture 30%, or 20%, or even 1% of an existing market before incumbents feel compelled to reinvent themselves around new technologies and business models. In the case of HTA commodities, this implies that VCPAs need not be a source of "forever subsidies" but can instead be seen as providing the "activation energy" to propel new production technologies through their "innovation" and "learning" phases to the point that the success of their incipient "scale" phase seems all but certain.

In Tesla's case, the innovation phase ran from, roughly, 2006 to 2014, as it developed the Roadster and demonstrated the viability of its technology and the potential of its business.

A rocky learning phase ran from 2014 through 2018 as the company transitioned from the niche Roadster to the Model S and the initial launch of the Model 3—a stretch that Elon Musk referred to as "manufacturing hell."

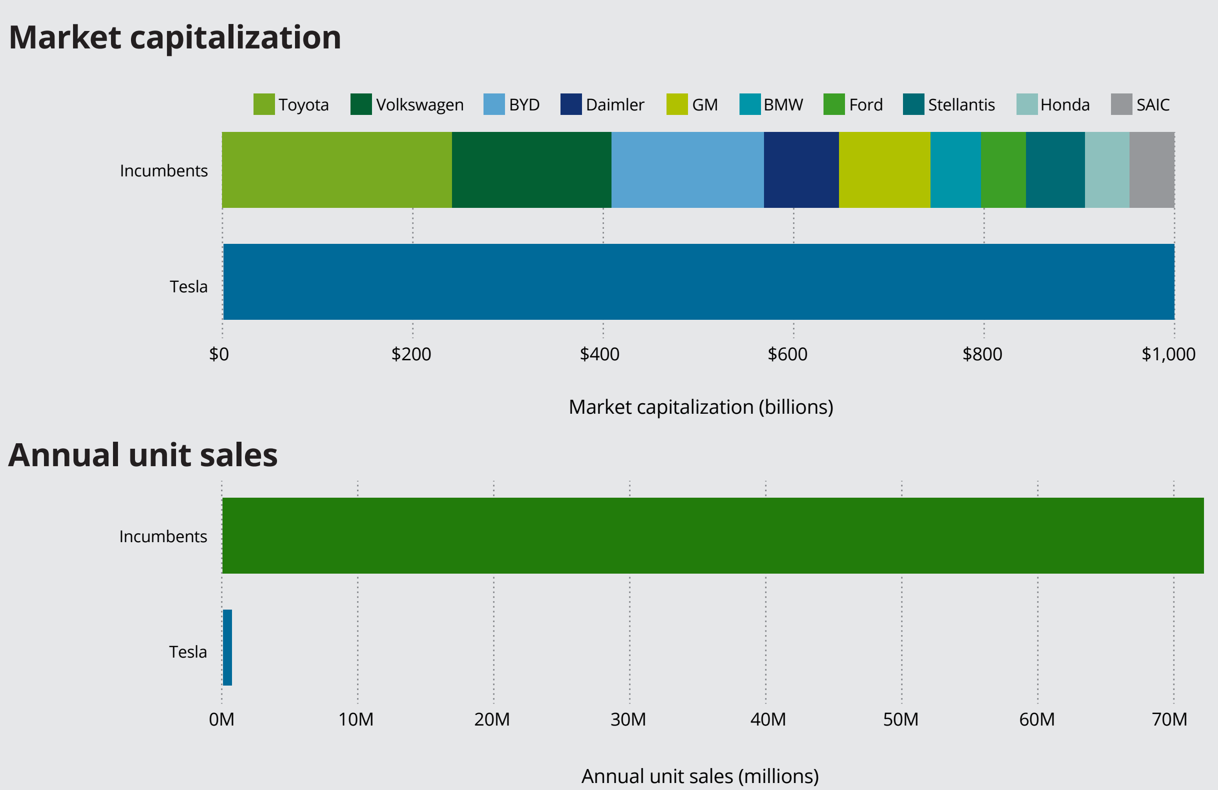
The transition to an incipient scale-up phase began shortly thereafter, and market sentiment seems to imply it might be a huge success: in 2021, Tesla had a market capitalization of more than US$1 trillion. That was more than the next 10 most valuable automakers combined—a group that included the erstwhile Big Three, Chinese makers SAIC and BYD, and the world's two largest car companies, Toyota and Volkswagen. Yet Tesla's volume was still less than one million units annually, or about 1/75th the volume of that same group of ten. (As of early 2024, Tesla's market capitalization of just under $600 billion was comparable to that of the next six most valuable automakers. Capital markets can be volatile.[22])

It is worth noting that, although the automotive market is capital-intensive on the supply side, and a big-ticket item on the demand side, it is a large and liquid consumer market, with tens of millions of individual buyers with a wide range of abilities and willingness to pay. And even so, government support has played a role in Tesla's evolution. Through 2015, for example, the US government provided grants, loans, and other subsidies of almost US$5 billion. Over that same period, thanks to luxury taxes on high-end gasoline and diesel-powered cars, Norway (of all places!) accounted for almost 10% of Tesla's total sales.[23]

Additional government regulations, largely in California, allowed Tesla to realize more than US$6 billion in revenue between 2018 and 2022 by selling carbon credits to other automakers. This might not seem like a lot in the context of the company's cumulative sales of US$240 billion, but against a backdrop of repeated cash crunches and ten years of uninterrupted annual losses through 2019, these infusions were very likely near-indispensable.

It is all but certain that, as with Tesla, government support of various types will be necessary to promote the decarbonization of HTA commodities, and such has been forthcoming. But that backing is unlikely to be sufficient—but not entirely, or even primarily, due to questions of quantity. Capital and revenue are not perfect substitutes. Both are essential, and Tesla's story suggests that every source of financing is critical. VCPAs are a mechanism that can provide the essential, incremental revenue needed to enable new technologies and processes to show what's possible. A transition of this magnitude is unlikely to be smooth and painless for all; uncertainties remain, and setbacks are likely. But whatever the future holds for any given EV maker, Tesla has shown the world that EVs are a viable alternative.[24]

Figure 6: Tipping percentage



Source: Wolfstreet.com; data for 10/25/2021

Fit for purpose

The type and quantity of VCPAs a company would need to purchase to achieve scope 3 supply chain net-zero are derived from carbon inventory estimates generated using the same spend-based EFs that most companies use today. Consequently, the solution described here requires only a recasting of existing estimates with entirely analytical methods: no new data, no new assumptions, required.[25] Consequently, the viability of VCPAs as a foundation for a credible net-zero claim depends upon the viability of current methods of carbon inventory estimation.

Spend-based EFs, however, are subject to an implicit and unavoidable level of inaccuracy. A company estimating its scope 3 burden from, say, legal services is assuming that the law firms it uses has the same "bill of materials" as the average US law firm. VCPAs, since they are based on these same inventory estimates, rely on the same assumption. To what extent, if at all, does this undermine the effectiveness of this general approach?

As both VPPAs and the Tesla example illustrate, VCPAs need not subsidize a particularly large percentage of any industry's production for a particularly long period of time. In addition, the solutions supported by VCPAs deliver radical decarbonization, not incremental improvements over our current worst practices. That is, just as VPPAs supported solar panels, not natural gas, and Tesla was building EVs, not ICE-electric hybrids, VCPAs for nickel are likely to be most effective when subsidizing 80%+ decarbonization, not at-the-margin improvements.

Since VCPAs are derived from existing carbon inventory methods, companies buying VCPAs to reduce their scope 3 burden could have a credible claim to legitimate net-zero status long before those companies not providing such subsidies. Preliminary modeling suggests that VCPAs can provide subsidies of 10%–100% of current market prices for many commodities for up to 1% of total production of HTA commodities. This level of support need call upon only marginally more companies than those that already see the business case for achieving net-zero, and that they be willing to spend on the order of 0.01% of revenue on these instruments—or $10 million for a $10 billion company. It is therefore at least plausible that there is sufficient latent demand for VCPAs to provide large enough price subsidies for long enough to transform a significant number of relevant HTA commodities.[26]

Neither does the success of VCPAs turn on their adoption by a majority, or even a large number, of companies selling VCPAs to secure the revenue subsidy guarantees needed to stand up (near) zero-carbon commodity production. The global automotive sector was transformed by a single company. Once, say, the "Tesla of concrete" shows the world what is possible, the dominoes will start toppling, first across the rest of the concrete industry, and then across the entire global economy.

Consequently, VCPAs do not have to, and are not intended to, support a long-term parallel carbon accounting system and a subsidy-based economy. Instead, VCPAs likely need be only of a magnitude and duration required to allow zero-carbon alternatives to fund their innovation, learning, and early-stage scale-up phases of development. When structurally zero-carbon solutions are just "how things are done," there is no need to subsidize low-carbon production or measure carbon footprints. If companies participating in a VCPA market can achieve their own net-zero status and the right commodities are decarbonized on the necessary time frame, the accuracy of the underlying estimate methods is irrelevant. Our collective intent, after all, must be to eliminate carbon emissions, not count them.

Everything, everywhere, all at once

For a company to claim a credible net-zero based on the decarbonization of its actual inputs, it would have to be able to show that, for example, all of the nickel that went into every input at every stage of its true supply chain was sufficiently decarbonized. That might be possible for one or two commodities, but the TR table reveals that every company is a user, eventually, of pretty much everything. And modern supply chains are sufficiently complex, opaque, and dynamic that no company of any significant size or complexity can reach actual net-zero through the decarbonization of the inputs used along its entire value chain until the entire global economy reaches net-zero.

Neither can we wait for costs to fall before we invest in decarbonizing HTA commodities, since it's investment that is needed to drive down costs. We can't tackle these commodities one at a time, either, because there are dozens of HTA commodities that all need to be decarbonized on the same compressed time horizon. In short, we need significant investment across a wide range of very different industries all at once.

With VCPAs, companies can put themselves in the vanguard of achieving a credible virtual net-zero. For example, based on the TR table, upstream grain production accounts for more than 6% of a pharmaceutical company's upstream scope 3 footprint, even though most pharma companies buy no grain directly. A portfolio of VCPAs that supports the decarbonization of grain and all the other invisible but essential commodities required to deliver lifesaving pharmaceuticals would effectively zero out the company's supply chain emissions.

Since VCPAs are grounded in the same carbon accounting principles already adopted by major standard-setting bodies, companies buying them could make the same claims to their customers and stakeholders that our low-carbon carmaker is after: the provision of net-zero products and services to their customers.

And since VCPAs, like VPPAs, would be supporting radical decarbonization, not merely marginal carbon reduction, companies selling them (the HTA commodity producers) would be able to claim that they, too, are driving the shift to net-zero.

To repeat: the intent of VCPAs is not to create a new carbon accounting and price subsidy tracking system that runs parallel to existing cost and financial accounting. After all, the necessary outcome is the 90%+ decarbonization of everything. If we succeed, then at some point, there will be no "high carbon" production of anything (more or less), and VCPAs will disappear. This system need only have the scale and scope necessary to support a relatively small fraction of each commodity's total production for a relatively short period of time.

As the Tesla case shows, after an initial period of support, market forces can be expected to reward and support the accelerating adoption of zero-carbon alternatives.

Virtual commodity purchase agreements, then, are not a long-term subsidy, but rather a mechanism for stimulating the initial investments needed to put low-carbon production technologies on the path to economic viability, large-scale deployment, and eventually market dominance.

However compelling this argument and however inspiring the precedents set by VPPAs in electricity and by Tesla's transformation of the consumer automotive market, we must collectively move much faster. The precursors to VPPAs were introduced in 1996 but were not recognized by GHG Protocol as a carbon abatement tool until 2015, and we still have a long way to go to fully decarbonize electricity generation. Tesla is a success almost without precedent, yet it took 20 years from its founding to the auto market's tipping point, and it will take another *10? 20?* years to replace ICE personal vehicles and achieve zero tailpipe emissions.

We don't have that kind of time. VCPAs are one way that companies with sincere net-zero ambitions can demand better.

Endnotes

1 See Sector by sector: where do global greenhouse gas emissions come from? - Our World in Data for data on sources and quantities of GHG gases. See Mark Z. Jacobson, No Miracles Needed: How Today's Technology Can Save Our Climate and Clean Our Air (Cambridge University Press, 2023) for a compendium of decarbonization technologies and processes.

2 The global transition to green electricity will require the production of at least 6 billion tonnes of additional metals between now and 2050. If this increase in production is achieved using existing technologies and processes, this is likely to imply increased production of key inputs to mining activities, including, for example, petroleum refineries (+US$40 billion annually), iron and steel mills (+US$18 billion annually), and tire manufacturing (+US$10 billion annually). Combined, the carbon footprint of the increased metals production amounts a minimum of one gigatonne of carbon annually, or almost 3% of current global emissions.

1. Deloitte and the Circle Economy Foundation, *The Circularity Gap Report 2023*, January 16, 2023.
2. Economist, "*Why it is time to retire Dr Copper,*" October 26, 2023
3. Economist, "How to avoid a green-metals crunch," September 11, 2023.
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6. Tesla, *Master Plan Part 3: Sustainable Energy for All of Earth*, April 5, 2023.
7. Vinve Beiser, *The World in a Grain,* (Riverhead Books 2018) and Ed Conway, *Material World: The Six Raw Materials That Shape Modern Civilization*, (Knopf 2023) as cited in Elizabeth Kolbert "*The Real Cost of Plundering the Planet's Resources*," The New Yorker, October 23 3023

3 Steel production generates CO2 emissions by generating industrial heat with fossil fuels and by separating oxygen from iron ore through a carbon reaction. Direct reduction substitutes green hydrogen for carbon, generating water rather than CO2, while industrial-level heat can be generated via green electricity or directly by concentrating solar energy. These changes can eliminate essentially all of the scope 1 (direct) emissions associated with steel production.

A similar story unfolds for most other HTA commodities, from cement to drywall to mining commodities to agricultural products: in every case, there are viable low-carbon production alternatives; what we lack is the willingness to pay for them.

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4. Mark Z. Jacobson, *No Miracles Needed: How Today's Technology Can Save Our Climate and Clean Our Air* (Cambridge University Press, 2023).
5. International Energy Agency, "*Cement*," accessed October 20, 2023.
6. Ben Tracy and Analisa Novak, "*Cement industry accounts for about 8% of CO2 emissions. One startup seeks to change that*," CBS News, January 16, 2023.
7. Thomas Kirk and Jessie Lund. "*Decarbonization pathways for mines,*" RMI, 2018.

4 The time from permit to production for new mines is typically a decade or more, and depends on many factors, including the type of mineral, the size and grade of the deposit, and regulatory requirements. Some commodities—coincidentally, those essential to large-scale electrification—can take almost twice as long: Copper, for example, averages 17 years to stand up a working mine thanks to the complexity of the transport infrastructure needed.

The long lead times suggest urgency in making low-carbon processes viable: For many mines, once the permitting process is complete, companies are, for practical purposes, often locked into using certain technologies; once construction begins, significant changes become all but impossible.

1. Audrey LaForest, "*Ford, Rivian urge faster permitting process for critical EV minerals*," Automotive News, August 31, 2022.
2. Mark Fellows, "*Permitting, economic value and mining in the United States*," SNL Metals & Mining, June 19, 2015.
3. Tehmina Khan et al., "*From commodity discovery to production,*" World Bank Group, September 2016.
4. Minerals Make Life, "*Congress makes modest headway on mine permitting reform*," June 15, 2023.

5 Hard-to-abate sectors account for about 30% of global emissions, or 12 gigatonnes of carbon annually (more than 40 gigatonnes of CO2e). For commodities such as cement, steel, and chemicals, production based on fossil fuels has long been and remains the most mainstream and cheapest option.

1. Laurent Auguste et al., *Mission Possible: Reaching Net-Zero-carbon Emissions from Harder-to-Abate Sectors by Mid-Century,* Energy Transitions Commission, November 2018.

6 In 2021, Swedish steelmaker SSAB sent Volvo the world's first shipment of low-emissions steel: 0.3 kg CO2 per kilogram of steel, or ~12% the carbon footprint of conventionally-produced steel – and a 25% higher price.

1. Alejandro de la Garza, "*The world's steel comes at a steep climate cost. A Swedish company is trying to change that*," Time, April 28, 2022.
2. Chathurika Gamage et al., "US businesses need low-emissions steel, and it's time for US steelmakers to get it to them," RMI, July 14, 2023.
3. Matt O'Leary, "*Volvo Group and fossil-free steel*," Volvo Group, November 28, 2022.
4. David Vetter, "How Sweden delivered the world's first fossil fuel-free steel," Forbes, August 19, 2021.
5. SSAB, "*FAQs: The big questions answered*," 2023.
6. World Economic Forum, "First Movers Coalition commit $12 billion to commercialize zero-carbon tech, cut emissions," November 7, 2022.

7 In 2017, the transportation sector surpassed the energy sector as the largest emitter of greenhouse gases. In 2021, transport accounted for 28% of total GHG emissions while electricity accounted for 25%. Energy from onshore wind and solar now costs about half as much as coal, and renewable energy—led by solar and wind. In 2022, wind and solar accounted for approximately 65% of new generating capacity.

1. EIA, "*Wind, solar, and batteries increasingly account for more new U.S. power capacity additions,*" March 6, 2023
2. EPA, "*Sources of greenhouse gas emissions*," October 5, 2023.
3. EPA, "*Overview of greenhouse gases*," October 10, 2023.
4. Katharina Buchholz, "*How wind and solar boosted U.S. renewable electricity*," Statista, March 28, 2023.
5. Simon Torkington, "*5 charts that show how renewable energy generation has soared*," World Economic Forum, November 3, 2022.
6. George Bilicic, "*Levelized cost of energy+*," Lazard, April 2023.

8 The process of technology adoption has been studied extensively. Despite the many and important differences among the dominant theories, there is one aspect of new production introduction they all agree upon: nothing big starts big.

Diffusion theory suggests that innovative customers, motivated by curiosity or a desire for prestige are willing to adopt relatively unproven solutions. Moore's "chasm" framework rests on the premise that bespoke solutions that more effectively address high-value needs can find their initial niche by appealing to price-insensitive market segments. Christensen's theory of disruptive innovation appeals to the notion of "new markets" – that is, not merely needs that are imperfectly met, but jobs that go entirely undone.

In every case, however, what is needed is some market segment willing to pay enough for enough production to enable the new entrant to one or both of improve performance and decrease cost in order to achieve mainstream success.

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1. Everett M. Rogers, *Diffusion of Innovations*, fifth edition (Free Press, 2003).
2. Geoffrey A. Moore, *Crossing the Chasm: Marketing and Selling High-Tech Products to Mainstream Customers* (Harper Business Essentials, 1991).
3. Christensen, Clayton M. and Michael E. Raynor (2003). *The Innovator's Solution: Creating and Sustaining Successful Growth.* Boston. Harvard Business School Press.

9 Noda's study of the development and deployment of wireless telephony services by the erstwhile so-called "Baby Bells" in the 1990s documents how companies with largely similar endowments and opportunities pursued very different pathways to large-scale deployment. Among his findings is the observation that, although all the wireless providers entered the market tentatively with relatively small-scale deployments, those that understood more deeply promise of innovation and scale to reduce cost and increase performance interpreted early market acceptance more positively than those who adopted a "cream-skimming" approach.

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10 Subsidies on the supply side (e.g., capital subsidies to producers of solar panels) and demand side (e.g., tax incentives and other credits for purchasing solar generation equipment) appear to have played a meaningful role in the rapid deployment of renewable generation.

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2. David M. Hart "*The Impact of China's Production Surge on Innovation in the Global Solar Photovoltaics Industry*," Center for Clean Energy Innovation, October 5, 2020.
3. German deployment: Anna Ivanova, "*Germany approves tax benefits for small solar installations*," Renewables Now, December 5, 2022.
4. US production: US Department of Energy, "*Federal tax credits for solar manufacturers*," accessed October 19, 2023 — but Phred Dvorak, "*The U.S.'s struggle to wean itself from Chinese solar power*," Wall Street Journal, November 15, 2022.
5. US deployment: Ann Carrns, "At 30%, solar panel tax credits are at a high point for now," New York Times, August 25, 2023.

11 A VPPA is a contract using Renewable energy Credits or Certificates (RECs) between a developer of renewable energy and an energy buyer. RECs provide proof that 1 megawatt-hour of electricity was generated from a verified renewable energy source. This energy is then used by the local power grid. RECs can also be traded and change value based on market demand. When the wholesale price of energy is higher than the contracted price the VPPA buyer gets financial gain. However, when the price of energy is lower than the contracted price the VPPA buyer must pay the developer the difference. VPPAs are typically set below the market price so that the buyers will receive payments at the beginning and there will be renewable energy benefits. The VPPAs lock in companies to a fixed price at today's rate so that they are protected against increasing energy costs over time. The contracts are not tied to a specific facility because they are virtual, so this allows for flexibility and the ability to secure carbon-free electricity at scale.

1. Duke Energy Renewables, "*5 things sustainability leaders should know about VPPAs*," Duke Energy Sustainable Solutions, December 2, 2020.
2. Mary Sotos, "*GHG Protocol scope 2 guidance*," GHG Protocol, accessed October 16, 2023.
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12 Corporate purchases of VPPAs accounted for 21% of deployed solar in 2009, dipping to 6% in 2014, before climbing steadily to more than 57% in 2020. This rise was coincident with the recognition by GHG Protocol of VPPAs as a mechanism of achieving corporate scope 2 net-zero in 2015. The global PPA industry was valued at US$ 20.1 billion in 2022 and is estimated to grow at a CAGR of 39.3% from 2023 to 2031 to reach US$ 399.2 Billion by the end of 2031.

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4. Transparency Market Research, "Power purchase agreement market."

13 Green hydrogen is estimated to cost 80% more than grey hydrogen.

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2. International Renewable Energy Agency, *Making the Breakthrough: Green Hydrogen Policies and Technology Costs*, 2021.
3. Jeff St. John, "*The problem with making green hydrogen to fuel power plants*," Canary Media, October 10, 2023.
4. Leigh Collins, "Switch to green hydrogen will lead to 'significantly higher energy prices in 2050 than today': Analyst," March 28, 2023.

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3. Worldsteel Association, "Steel in automotive"

15 An agriculture supply co-op aggregates storage, purchases, and distribution for the member farms making it difficult to connect output with upstream emissions from specific farms.

Mining commodities are shipped to facilities that commingle inputs from different mines in ways that make it impractical to attribute specific inputs to the finished steel.

Commingling of this sort can make it difficult for companies to track their upstream supply chains with sufficient precision and detail to support securing scope 3 emissions reduction benefits from their support for the decarbonization of specific upstream suppliers.

Recognizing this, GHG Protocol is developing guidance that allows companies to recognize scope 3 reductions even if their support does not translate into the decarbonization of the precise inputs a company ultimately uses.

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2. Shelby Myers "*Analyzing Farm Inputs: The Cost to Farm Keeps Rising,*" American Farm Bureau Federation, March 17, 2022
3. SimpleShowing "Agricultural Steel Buildings: A Cost-Effective Solution for Your Farming Needs," April 18 2023
4. Greenhouse Gas Protocol, "*Greenhouse Gas Protocol Survey on Need and Scope for Updates or Additional Guidance*"
5. Greenhouse Gas Protocol, GHG Protocol Agricultural Guidance

16 An analysis of the BEA's Input-output tables reveals that electricity ranks between the 98th and the 100th percentile most significant input for 95% of US-based production of all commodities. By way of comparison, iron ranks between the 0th and 98th percentile. In other words, everyone buys electricity to some degree, while only a very few industries buy, say, raw metals, directly. With essentially every company purchasing electricity, and an increasing number of companies using VPPAs to achieve scope 2 net-zero, the market for these instruments is large and liquid.

The price of VPPAs, however, like the price of electricity, fluctuates rapidly and widely. In 2023 Q3, the inter quartile range for PPA prices was between $52 and $80. However, the median PPA price was highly depended on the region and weather it was for solar or wind. For example, the median wind

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PPA price in the Midwest was $35.37 whereas, in the mid-Atlantic region the median price for a solar PPA was $75. These large variable prices are also reflected in the European PPA market. The interquartile price range was us$72-$97. These median prices are highly dependent on the country.

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4. DGB Group, "*Tesla's Carbon Credit Sales Soared to $1.78 Billion in 2022*." March 07, 2023.
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13. Sinbon "*How Tesla Made Great Profits from Regulatory Credits*," Accessed October 16, 2023.
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19 Root, Al. "BYD Is Now Bigger Than Tesla After Record Quarterly Sales". *Barron's*, January 2, 2024. https://www.barrons.com/articles/byd-bigger-tesla-after-record-quarterly-sales-297e464e. Accessed 02/02/2024.

20 https://www.greencitytimes.com/global-ice-vehicle-phase-out/. Accessed February 9, 2024.

21 On September 23, 2020 California governor Gavin Newsom issued an executive order that all new cars and trucks must create zero emissions by 2035. This ICE vehicle ban will take place in stages. First, by 2026 35% of new-car sales must be zero-emission vehicles (ZEVs), 68% by 2030, then 100% by 2035. This order is enforced through both fines and incentives. A $20,000 fine is issued to automakers for each new vehicles that is sold in violation of the target. This plan also includes a state investment of $2.4 billion for purchasing incentives, public outreach and charging infrastructure. This ban has influenced New York's governor to sign a new legislation (A.432/S.2758) into effect on September 8,2021. This legislation requires all new cars and trucks sold in New York to be Zero Emission by 2035.

ICE vehicle bans have also expanded internationally. On November 16, 2020 Canada's minister announced a law that includes the ban of ICE by 2035. This ban that will follow the same timeline as California's.

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23 Norway has a population of less than five and a half million people. A nordic country, it enjoys long stretches of cold weather, which can compromise the performance of electric vehicles; and although this is less of a concern today, thanks to technological advances, a decade ago this might well have been material in the eyes of some buyers.

It seems likely that a variety of regulatory, legislative and tax code incentives, large and small, played a role. These include reduced registration fees and VAT for corporate and personal purchases, free parking and ferry use, access to bus lanes, and reduced road tolls. This served both to reduced the purchase price and operating costs of EVs and provide constant, perhaps daily, reminders of these inducements.

https://blog.wallbox.com/how-norway-became-a-global-ev-leader/

24 There are, not surprisingly, critics of both EVs as a technology and the current mechanisms supporting the adoption of EVs. The notion of the Gartner HypeCycle is perhaps instructive (https://www.gartner.ca/en/methodologies/gartner-hype-cycle). Transitions of far less import than the shift to EVs seem typically to pass through a "trough of disillusionment" before taking root and ramping up to full scale adoption. In evaluating the likelihood of the long-term success of EVs, it can be useful to assess both the drivers and impediments in terms of their structural versus transitory nature.

25 See Raynor, Michael E., "*Reducing Supply Chain Emissions*", Deloitte Insights

26 Commodity production accounting for approximately 20% of US GDP generates 92% of total emissions. Assume these commodities are "selling" VCPAs, and that the commodities accounting for the other 80% of US GDP are "buyers" of VCPAs. If 20% of potential VCPA buyers (by revenue) spend 0.05% of revenue, 0.2% of production of all HTA commodities will have a 20% price premium.

This analysis will be explained in greater detail, and the implications explored more fully, in a forthcoming Deloitte Insights publication. Contact the author for more detail.

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