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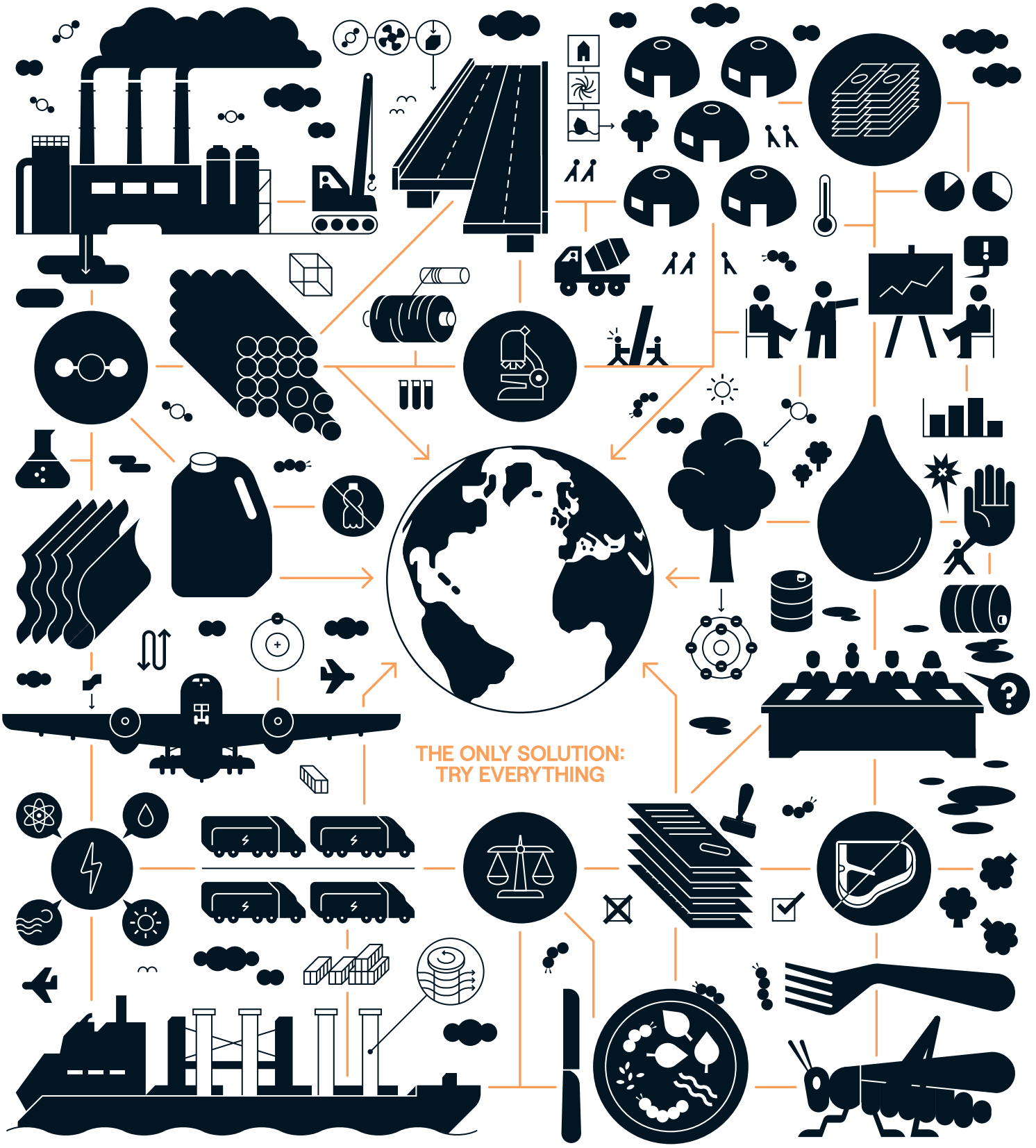
The Climate Issue



The Climate Issue: Has the Carbontech Revolution Begun?

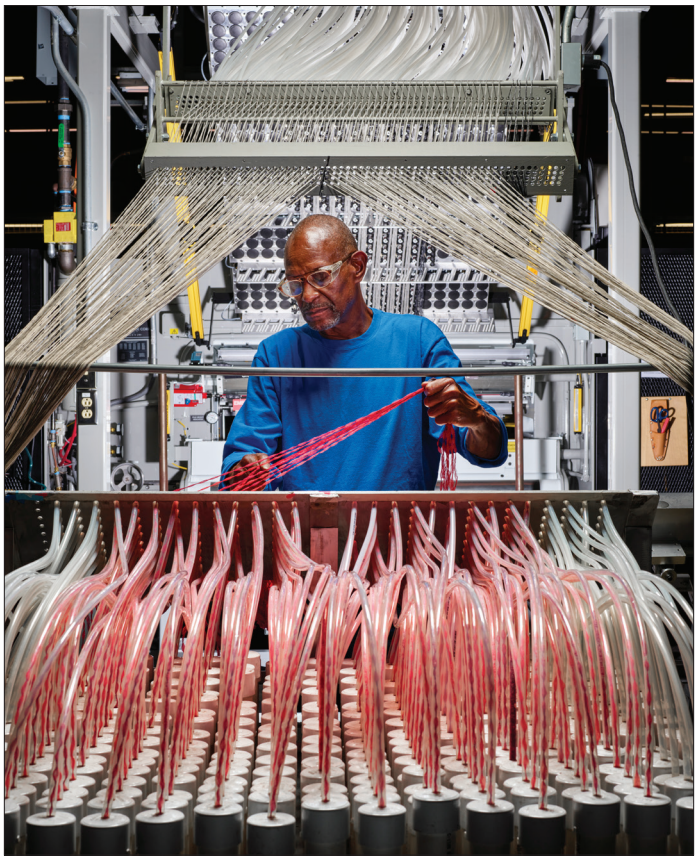
By Jon Gertner

You have probably set foot on Interface products. The company, based in Atlanta, makes commercial flooring — carpet tiles, lightly napped, highly durable, easily overlooked in the commercial offices and educational facilities where they are mostly in use. When Interface sent me samples of its newest product earlier this year, at a glance they seemed banal, familiar: These were the marled gray patterns that cover the floors of airport terminals, corporate hallways and CVS pharmacies all over the world. How many miles had I walked on those carpets?

Yet in their very composition, they were something new. This carpeting was a result of four years of intensive research and development, according to Interface. It incorporated a material made from recycled vinyl and processed vegetation; it was infused with a latex created from smokestack exhaust. It was topped and tufted with salvaged nylon. And it had been manufactured in the least environmentally demanding way possible. By Interface's reckoning, the carpeting had a carbon footprint of negative 300 grams per square meter. "It's not a magic material," Erin Meezan, chief sustainability officer at Interface, told me recently. But the math does have a magical quality to it: In part because of how the carbon is sourced, carpeting a 10-feet-by-20-feet conference room, say, with these tiles can be seen as the equivalent of pulling roughly 12 pounds of carbon dioxide out of the atmosphere.

For decades, Interface has made most of its domestic carpets at a cluster of factories in LaGrange, Ga., about an hour southwest of Atlanta. John Bradford, its chief science-and-technology officer, led me on a tour one afternoon as he explained the company's reconfigured manufacturing processes. "We recycle every frigging thing," he said. His work goes far beyond recycling, however. Interface requires a detailed accounting of the company's renewable energy sources, exhaust fumes, supply chains and waste streams. Some of the immense machinery, akin to blocklong newspaper presses, where hot sheets of vinylized carpet filler are rolled out, now runs at lower temperatures to save energy. A short distance away, a recycling center the size of several gymnasiums was crowded with rows of fabric sacks overflowing with nylon filaments, rescued from factory trimmings, ready to be turned into the face cloth for new carpet. The noise was deafening as jumbo fabric shredders, extruders, hoppers and conveyors rumbled away. Things quieted down only when we visited the company's design center: From floor to ceiling, in aisles resembling a supermarket that sold color rather than food, were huge spools of yarn, all recycled, in every conceivable hue.

Industrial carpet tile can be thought of as a kind of three-layer sandwich, made from tufting on top, filler in the middle and backing on the bottom. In the mid-1990s, Interface calculated the carbon footprint of these layers and concluded that a square meter of the sandwich was responsible for releasing about 20 kilograms worth of CO_2 into the atmosphere. Most of these emissions — probably more than 70 percent — resulted from materials and processing, and a lesser portion from manufacturing, installation and maintenance (all that cleaning and vacuuming over the course of a carpet's life adds up to significant CO_2 emissions). "So, when you start to go from where Interface was in the 1990s, which was 20 kilograms per square meter, and subsequently make progress to get it to 12, then to nine, then to six, and now to get it to negative, the biggest levers we pulled were making the raw materials different," Meezan told me. The company began using recycled components for the backing, filler and yarns, and the factories were refitted with machines that were more efficient. Pushing an Interface product to below zero, at least in carbon terms, was not about a big breakthrough, Bradford pointed out. It was more like coming up with



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Gary L. Boddie, a team leader at Interface, tufting carpet.

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The carbon-negative carpet backing made by Interface incorporates biomaterials including forestry byproducts and plants rich in absorbed carbon.

Collecting product scraps at Interface to reuse in carbon-negative backing.

a recipe involving hundreds, if not thousands, of changes to ingredients and techniques.

Over the next two decades, the company learned a couple of things. First, by reducing its emissions and using mostly recycled materials, its tiles could approach carbon neutrality. Second, by obtaining its materials from different sources — and using them in smaller amounts — Interface could further shrink its footprint. The CO2-infused latex, which is sprayed on the carpet's middle layer, was a helpful step. The key adaptation, however, was transforming the backing. Incorporating biomaterials — forestry byproducts and plants rich in absorbed carbon — locked in high levels of carbon and canceled out the emissions related to the rug's materials, production and life cycle. In essence, Interface was creating what we usually call a carbon offset in the lowest layer of its carpet sandwich.

Meezan told me that some rivals in Europe and Asia have begun marketing carbon-neutral tiles, but they have yet to mimic Interface's negative product. But she hopes customers will soon demand that every company making stuff for what she called "the built environment" — carpets, furniture, drywall and the like — will provide carbon-negative goods. By some estimates, nearly 40 percent of global CO2 emissions comes from buildings and construction, a level that Meezan notes is unsustainable. "That's why we're doing this," she said.

Interface is far from the only company trying to "embed" large amounts of carbon within commercial merchandise. For the past few years, a number of start-ups have begun developing products that aim to fold in carbon dioxide captured from smokestacks and other sources of pollution, in an attempt to reach a new level of environmentally friendly manufacturing: one in which greenhouse-gas molecules are not only kept out of the atmosphere but also repurposed. This undertaking, usually characterized as carbon utilization, goes well beyond flooring — to plastics, jet fuels, diesel, chemicals, building materials, diamonds, even fish food.

Advocates of carbon utilization, or carbontech, as it's also known, want to remake many of the things we commonly use today. But with one crucial difference: No emissions would have been added to the environment through their fabrication. Carbontech sees a future where the things we buy might be similar in their chemistries and uses but different in their manufacture and environmental impact. You might wake in the morning on a mattress made from recycled CO2 and grab sneakers and a yoga mat made from CO2-derived materials. You might drive your car — with parts made from smokestack CO2 — over roads made from CO2-cured concrete. And at day's end, you might sip carbontech vodka while making dinner with food grown in a greenhouse enriched by recycled CO2. Many of these items would most likely be more expensive to the consumer than their usual counterparts, in part because they often need significant amounts of energy to make. But the hurdles to making them are no longer insurmountable.

Noah Deich, a founder of a nonprofit think tank called Carbon180, told me that he sees the market for carbontech products potentially reaching $6 trillion globally. By far the largest part of that economy, should it become a reality, would derive from the refashioning of commodities like building materials, concrete, fuels and plastics. But a yoga mat might not be irrelevant. "It doesn't trivialize carbontech; it humanizes it, since usually with CO2 you can't touch it," says Deich, who advised the Biden transition team on carbon policy. "You're not going to save the planet by drinking carbontech vodka," he adds — but a consumer good like that might help alter our consumption ethos. Rather than using, we would be reusing.

Even during the pandemic, a number of carbontech ideas began moving from the realm of green idealism into proof of concept. But energy legislation finalized at the end of the Trump administration, along with the arrival of Biden-administration cabinet members like Secretary of Energy Jennifer Granholm, have accelerated the progress. The federal government offers incentives, under a tax provision known as 45Q, to spur companies to use CO2 commercially or bury it underground, thereby removing it from the atmosphere. In recent years, about $20 million has been allocated annually to carbon utilization, in order to strengthen fledgling markets for new products that incorporate recycled CO2. This push is enhanced by far larger federal authorizations — around $6 billion worth — to eventually expand a process known as carbon capture and storage, or C.C.S., through which millions of metric tons of CO2 are sucked from places like factory and power-plant smokestacks and stored. Beyond what's kept underground, some of that gas could easily be diverted into products. It might, for example, go from a power-plant smokestack to a factory where the gases are digested by bacteria to produce fuel for airplanes.

Volker Sick, a professor of mechanical engineering at the University of Michigan who runs the school's Global CO2 Initiative — its mission is to make carbon utilization a mainstream pursuit for U.S. industry — believes that carbontech offers a counterpoint to the pre-

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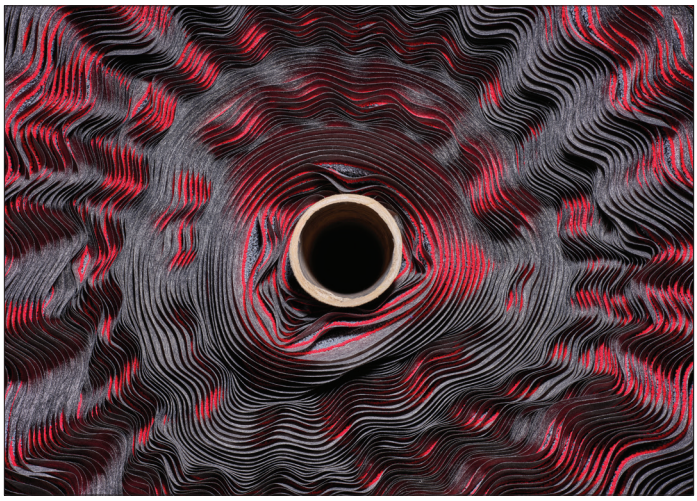
Lonnie Murphy, a team leader, overseeing carpet being cut into tiles.



A roll of carpet ready to be finished with carbon-negative backing.

vailing thinking about CO2. It assigns a value to the gas and allows us to imagine it as not only a problem but also a resource. "Think back maybe 200 years, when this whole Industrial Revolution began, when we moved away from what was largely a circular economy to one that's extractive," Sick says. "We began to take from the earth, use and then dispose. So, I think we need to use things in a circular way again. And the way it works is not that we go back to before — build a log house and hunt and collect berries. There are too many of us around. We have to have industrial processes." An essential aspect of a circular carbon economy, Sick notes, would involve using renewable, emissions-free energy to put CO2 into products. "That's the real linchpin for this whole thing," he says.

Sick's larger argument is that utilization makes practical sense, because we may not be able to bring a hard stop to our carbon-consumption habits. Plastics made from petrochemicals are essential for medical supplies like syringes, for instance. There are currently about 1.4 billion cars and trucks in the world, and almost all of them run on gas or diesel fuels, which makes Sick question whether we can switch to electric vehicles as rapidly as some advocates hope. But if companies begin to change the sources and supply chains for carbon-based fuels and materials — no more buying oil taken from the ground, in other words — that could help neutralize the effects of our transportation systems and change the way we live. Maybe, too, it could change the way we think. "We talk about decarbonization," Sick says. "But mostly, I think, what we actually need is defossilization."

A carbontech future does not mean a high-tech makeover for everything we use. A growing movement to construct large commercial buildings out of timber, for instance — recently, a 280-foot-high wood office tower went up in Norway — follows a time-tested way to take CO2 from the atmosphere while avoiding the emissions generated by steelmaking and the production of concrete. Big wooden structures can embed more than a thousand metric tons of carbon that have been naturally absorbed by trees; just as crucially, they can sequester it from the air for many decades or perhaps centuries. Timber skyscrapers may prove more straightforward in their engineering than other carbontech products, though. For most of the things we buy and use, defossilization may depend on novel manufacturing techniques and innovations. It also requires pushing hard against historical convention — the circumvention of several hundred years of industrial evolution and dependencies on oil and coal.

While Interface's carpet tiles are carbon negative as a result of myriad small improvements, some carbontech products rely on a singular idea, or a large technological leap, to reformulate old products. Concrete is a good example. A composite product made from cement that binds together sand and gravel (ingredients typically known as "aggregate"), concrete is one of the most vexing challenges in addressing climate change. Its cement content accounts for about 7 percent of annual global CO2 emissions, at the same time as it is resistant to commercial innovation, largely because it has a standardized recipe that satisfies most building codes. In the past few years, CarbonCure, a Canadian company, has successfully introduced a workaround. It takes recycled CO2, supplied by contractors who capture it from factory exhaust, and injects the gas into a mix so that it can infiltrate and mineralize in the concrete. The upshot is twofold: CO2 is sequestered (producing concrete this way reduces emissions by 5 to 8 percent compared with typical mixes), and the addition of the gas creates a stronger material.

Eric Toone, a leader of the investment committee at Breakthrough Energy Ventures, a firm started by Bill Gates to direct billions of dollars toward climate-related technologies, told me his colleagues view CarbonCure, one of the firm's investments, as a good step toward the remaking of the industry. The world's challenge when it comes to construction, Toone says, is so large — by some estimates, we will build the equivalent of another New York City every month for the next 40 years — that it will ultimately require a more innovative concrete mix that employs a different chemistry to actually become carbon neutral

or even carbon negative. “So, is CarbonCure the whole answer?” he says. “Absolutely not. But it’s a start on an incredibly difficult problem.”

Carbontech fuels face similar obstacles. In Skokie, Ill., a company called LanzaTech has spent more than a decade designing bacteria that digest carbon gases and produce fuels like ethanol. The air in the company’s labs, where small so-called bioreactors are fed carbon monoxide and other gases in order to test different bacterial recipes, is pungent with fermentation. Jennifer Holmgren, LanzaTech’s chief executive, told me there that its immediate strategy is to place its technology next to industrial plants around the world, where it can capture carbon emissions at the source. “They have carbon, and they have energy for the organism,” Holmgren said. “I can pump that into a bioreactor and make ethanol.” Or, she said, she could employ other LanzaTech bacteria that would digest the same ingredients and yield a different product, like acetone for nail-polish remover or chemicals to make industrial foams or gels. In April, the company’s ethanol was used to produce a chemical ingredient for a Unilever laundry detergent sold in China, where LanzaTech now has two working plants.

Company founders and investors sometimes discuss their prospects in terms of “technology readiness levels,” or T.R.L.s. This engineering jargon is a ratings scale — 1 as the least mature technology, 9 the most developed — that was created by NASA in the 1970s as a means to evaluate the technologies developed by its suppliers. Today you might hear carbontech entrepreneurs say something like “Our T.R.L. is now at 6.” Interface’s carbon-negative carpets would be at the top of the scale; they are already being sold globally. CarbonCure, too, has advanced to complete readiness. So far, CarbonCure estimates that it has delivered more than a million truckloads of its carbon-injected product to construction sites — while having prevented nearly 100,000 metric tons of CO2 from entering the atmosphere. Another concrete whose production generates fewer greenhouse-gas emissions than conventional versions, made by a New Jersey firm called Solidia, is now sold as paving tiles and as a lower-carbon cement mix. In short, carbon utilization is furthest along for building materials, technologically speaking, with fuels slightly behind. A new company spun out from LanzaTech, known as LanzaJet, is in the process of building a plant in Georgia to make jet fuel from ethanol that in turn comes from organic waste products (which will eventually include carbon waste gases).

These three companies — Interface, CarbonCure, LanzaTech — arguably represent the global carbontech vanguard. Behind them, dozens of start-ups are trying to get their goods to market. In Berkeley, Calif., I visited a company until recently known as Opus 12 but now called Twelve. It is refining a process, first discovered by Japanese scientists in the 1970s and further developed by Kendra Kuhl and Etosha Cave, two of the company’s founders, that uses metal catalysts to transform CO2 by bubbling it through water. This yields the building blocks for polymers, chemicals and fuels. The firm is seeking to become the world’s first fossil-fuel-free chemical company and to brand consumer items, like sneakers or sunglasses, with “Twelve,” much the way waterproof shoes or jackets carry a Gore-Tex badge. Last year, Twelve collaborated with Mercedes-Benz to demonstrate that a structural pillar for a car’s interior could be made through its CO2 utilization process. At first view, this wouldn’t seem to offer much of an environmental impact. But one of the firm’s founders, Nicholas Flanders, told me that the payoff for making car parts from recycled carbon could be substantial. “There are currently about 300 kilograms of polymers in every new car,” Flanders said, “and that’s going to be the case even for electric cars, too.”

On another day, I went to see Solid Carbon Products in Provo, Utah. “I’ll show you what we’ve built,” Gay Wyn Quance, who runs the company, told me, as we entered a vast workroom. There, a demonstration

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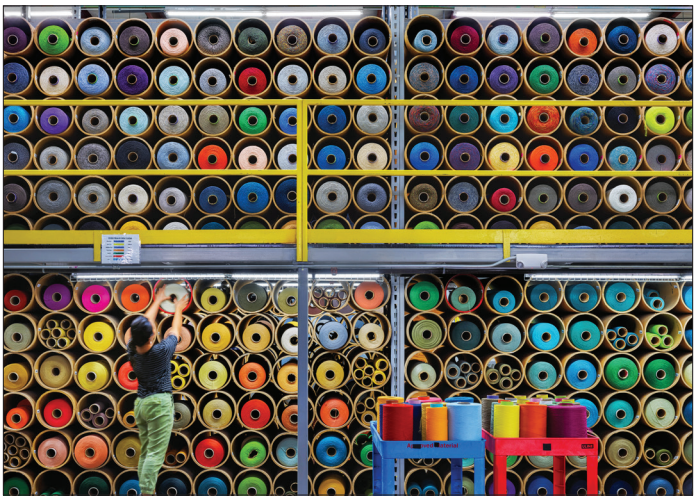
Barbara Moore, tufting technician.

model, a towering network of tanks and pipes, fed by CO2 tanks, turns waste gas into solid carbon particles. The particles are used to make a very strong carbon-fiber material, or to make a substance called carbon black, which can be used as a raw material in things like car tires. In both instances, the end products from Quance’s machine were jet-black powders that feel smooth and dense between your thumb and forefinger. Quance is now working with Goodyear to explore using her company’s carbon black to make car tires sustainably. Still, the road to commercialization looks to be long. Goodyear says it intends to start selling its first sustainably sourced product in 2030. It is likely to be even longer before carmakers create a mass-produced automobile with an affordable carbontech body.

Carbontech can’t produce a solution to climate change, no matter how fast it gets into the marketplace. Getting global CO2 emissions close to zero by around 2050 — which is what will be needed to keep temperatures from rising by dangerous increments by century’s end — means drastically reducing our recent annual global output of more than 31 billion metric tons of CO2. The best way to eliminate that tonnage is by switching over as quickly as possible to renewable energy and cleaner transportation and heating systems. As a rule of thumb, it is always easier to reduce CO2 emissions by avoiding fossil-fuel burning rather than finding ways to bury (or use) the gas emissions after the fact.



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Spools of yarn at Interface. Materials and processing account for a majority of the CO2 emissions associated with making carpet.

Cathy Boykin, seamer transporter.

Nevertheless, carbontech products might help during what is sure to be a difficult energy transition. This is especially true in economic sectors that, for technological reasons, are hard to electrify, like jet planes, or for industrial processes that are hard to decarbonize, like making cement, steel or fertilizer. "I think you can imagine, in a circular carbon economy, with a lot of CO2 utilization, you could put on the order of a couple of billion tons into this stuff each year," says Julio Friedmann, a senior research scholar at Columbia University and an expert on carbon-removal technologies. "So, you can't balance the climate books this way, but you can really make a big dent. And the thing that's nice about binding CO2 into aggregates, for instance, or into cement, is that's effectively permanent. It is not going anywhere for human history. We have 2,000-year-old concrete. You have to work hard to liberate the stuff."

But does it make sense to also pour CO2 into yoga mats and sneakers? "Let's take a little step back," Friedmann told me. "At the end of the day, it's good to try everything. We are in such hot water, literally, that the idea of, 'What's the optimal way to do this?' is very far in the rearview mirror. So, if someone wants to turn CO2 into a plastic and sell it in a shoe and get market share, I'm an enthusiastic proponent of it. Does it move the needle? Nobody knows."

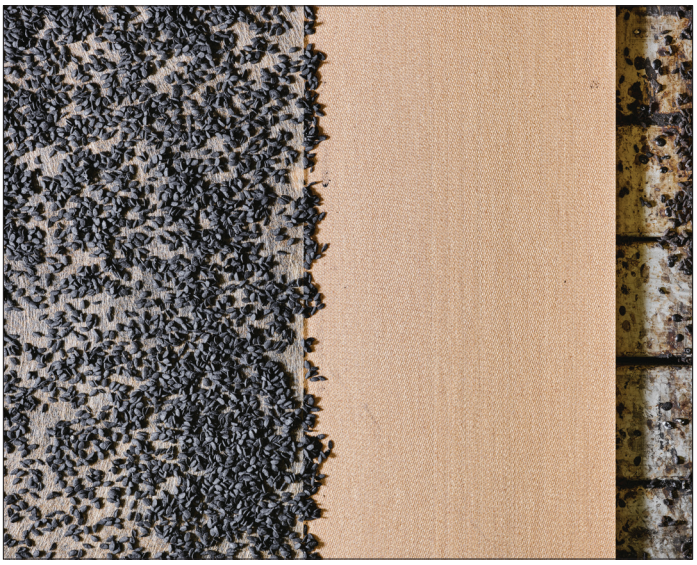
A thriving market for carbontech products would at least be likely to increase demand for CO2 as a raw material. The gas would probably have to come from factories and power plants, whose emissions are now mainly left to drift into the atmosphere. (At the moment, 12 commercial-scale facilities in the United States capture about 25 million metric tons of CO2 annually, representing a tiny fraction of total power-plant and factory emissions.) A thriving CO2 market might likewise spur demand, and drive down prices, for a fledgling technology known as direct air capture, which uses machines to remove CO2 straight from ambient air, rather than from factory smokestacks. But this raises the potential challenge of getting all that captured carbon to where it could be used. A carbon economy of the future would need a huge network of pipelines to move the gas around the country, taking it from emissions sources to places where CO2 can either be buried permanently deep underground or incorporated into products. To this end, a bipartisan roster of Senate and House members recently proposed federal legislation known as the SCALE Act, which urges Congress to spend about $5 billion on a vast, nationwide carbon transport and storage network.

New pipelines and markets for recycled carbon wouldn't necessarily settle the politics of an energy transition, though. An expanded carbon economy could extend the influence of fossil-fuel purveyors and delay a switch to electrification and renewable sources of energy. In other words, technologies meant to help counter climate change could cause some of the problems to linger. Last year, in a letter to Congress that argued for a more progressive energy bill, more than 100 environmental groups, including Friends of the Earth, made the case that efforts to capture and store carbon were, in the words of one coalition member, "false solutions."

But even political consensus and federal funding cannot guarantee that carbontech companies will reach commercialization, a journey that most start-ups fail to complete. When I asked Jennifer Holmgren, the head of LanzaTech, how her microbe-made fuels could compete against fossil fuels, she acknowledged it would be difficult based on price alone. Using recycled CO2 or carbon monoxide simply costs more than refined oil. "There are two reasons you can't compete with incumbents," she said. "One is all that infrastructure that's been built for the fossil-fuel companies. But the other is getting down the cost curve. With any new technology, it can take 30 or 40 years." Holmgren intends to make a product as close as possible in price to fossil fuels, but with the added appeal of sustainability. Equally important, though, would be an opportunity to take advantage of mandates for government agencies and big companies to buy carbon-neutral or carbon-negative products.

This kind of procurement, as it's usually called, is now the animating hope for carbontech, and for good reason: It could create enormous demand for a product that is priced too high for market competition. Procurement spending, which has been essential in developing the wind and solar industry, can help an immature company or product gain scale and efficiency. "The U.S. military buys about 4 percent of the nation's fuels," Julio Friedmann told me. So a policy that calls for some of its purchases to be carbontech fuels would make a huge difference. The U.S. Postal Service, as it begins to switch its fleet over to electric vehicles, could also buy carbontech fuels for its existing trucks. State governments could use low-carbon concrete in new buildings and road repairs. Federal offices could be carpeted with carbon-negative tiles. Indeed, the Biden administration's proposed infrastructure and climate plan shows a willingness to spend billions of dollars on procurement. "If the government would, in addition to buying American, buy low carbon?" Noah Deich of Carbon180 mused. "Well, there's no better customer than the U.S. government."

Some boutique products, like carbontech vodka or sneakers, would al-



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most certainly not qualify for procurement funding. Purveyors of goods like those would instead have to rely on conscientious consumers. Yet history suggests that modest applications can still push technologies forward. "Lithium-ion batteries entered the market on camcorders," Friedmann points out. "And camcorders barely exist anymore. But having that platform pushed the technology along." Making and selling those batteries, in other words, made them increasingly cheap and efficient. And eventually, they came to power electric cars.

The last time investors began moving billions of dollars into young, climate-oriented technologies, things didn't turn out so well. The few big successes from the early 2000s — Tesla, for instance — were offset by a multitude of green investments that were either uncompetitive in price or came up short on technological readiness. But all the green investors I spoke with seemed to have concluded that there are enough differences between the world of today and the early 2000s, not just in technology but in urgency and policy as well, to suggest different results this time. Two decades ago, climate change hadn't wrought the floods, fires and heat waves that now give us horrifying glimpses of the future. Steady gains in renewable-energy technologies like wind and solar had not yet shown they could compete with fossil fuels. And a slew of new climate-friendly regulations in states like California had not yet expanded the market for low-carbon products. According to the International Energy Agency, global investments in low-carbon energy are now hitting about $600 billion annually. And the money is coming not only from venture-capital firms like Breakthrough Energy Ventures but also from private investors at family foundations and firms like Goldman Sachs and BlackRock, whose chief executive, Larry Fink, has become an evangelist for the green economy. "The climate transition," Fink recently proclaimed, "presents a historic investment opportunity."

How carbontech fits into a green economy of the future seems more difficult to predict. Companies like Microsoft and Stripe, a payments-technology firm, have already decided to sink millions into carbon-utilization firms and other carbon-removal efforts. Lucas Joppa, Microsoft's chief environmental officer, told me he thinks a utilization market is not only necessary but also sensible, especially because we think of carbon as a waste product. One man's trash can always be another man's treasure, he notes. "Carbon is the building block of life. I mean, if we can't figure out meaningful things to do with it, well, then shame on us."

But a number of things need to happen to make such a transformation possible — essentially, an entire CO2 "value chain" must evolve into existence in order to feed carbontech firms with clean energy and raw materials and also create markets for their goods. At the same time, a rigorous CO2-accounting system, along with third-party audits, would need to take root, to show the environmental impact of these products. Daunting as all this sounds, assuming the world continues to consume carbon products, utilization could offer something new and traditional: an alternate "pathway" for CO2 emissions that gives us better odds of ensuring a livable climate. Burying most of those emissions deep underground would no doubt be necessary and give us enormous environmental benefits. Embedding them within products, meanwhile, might result in a broad economic payoff as well.

In the long run, too, carbontech might prove to be a good business for some firms. Interface views its negative-carbon tile as a way to serve a raft of increasingly motivated government agencies and companies. Amazon, Apple and FedEx are now committed to eventually being carbon neutral, and others (like Microsoft) have set their sights on being carbon negative. As companies further define what sustainability means, Meezan told me, "they're going to come face to face with the realization that what they're doing on climate is not adequate." And when that moment comes, she predicted, they'll have to ask: What comes after net-zero carbon?

Interface is there already, which gives it advantages as both a vendor and a role model. "Who really cares if this tiny carpet company is making something like this tile?" Meezan put it to me rhetorically. "We do," she answered, meaning the 3,800 employees who work at her company. And because the product was the first step of a larger goal — for the entire firm to become carbon negative by 2040 — she considered it a way to show others that the carbon problem isn't impossible to solve. "If a company like ours has been able to get to carbon negative," she added, "then you can be optimistic about what that means for Starbucks, or the Gap, or other companies." A ripple effect had already reached other makers of the built environment, she told me — furniture firms, building-materials makers and the like, which all need to meet standards for greener buildings. She was not under the impression that this would change the world immediately. But what would happen, she wondered, if all the players in the post-pandemic economy started thinking negative, too?