ABOUT TRUST

THE MAGAZINE OF THE TÜV SÜD GROUP 01 — 2022

Add value.
Inspire trust.

Focus: **RENEWAL**

Hermit crabs are masters of reusing discarded things, confirming the proverb that one person's trash is another one's treasure. We could learn a lot from this behavior, for instance in the structuring of our economy, when composing music or in the search for the really grand solutions of the computer age.

ABOUT
TRUST

DEAR READERS,

If you don't move with the times, you'll get left behind—as the saying goes. Continuous renewal is part of our lives. Nature never stands still, and constant striving towards advancement is something that seems to be part of our DNA.

We've devoted this entire issue of ABOUT TRUST to the topic of renewal in many of its forms. Since its foundation back in the nineteenth century, TÜV SÜD has promoted new, advanced technologies—while ensuring that they remain in harmony with our environment and society. It has always been our goal to make new developments safer and to create trust in them, thereby making progress possible in the first place.

Sustainability has always played an important role in this—and not just since the topic became fashionable, so to speak. Ensuring the efficiency of technologies and determining how people can sensibly and safely use them have always been core tasks for TÜV SÜD. Protecting our environment from technically induced risks has been a recurring theme over our many decades of work. We renewed this approach in 2021, setting the goal of becoming the most sustainable company in our industry and supporting our clients to become sustainable as well. This, too, is renewal in action!

I hope you enjoy reading this issue!

PROF. DR.-ING. AXEL STEPKEN
Chairman of the Board of Management of TÜV SÜD AG

01 2022

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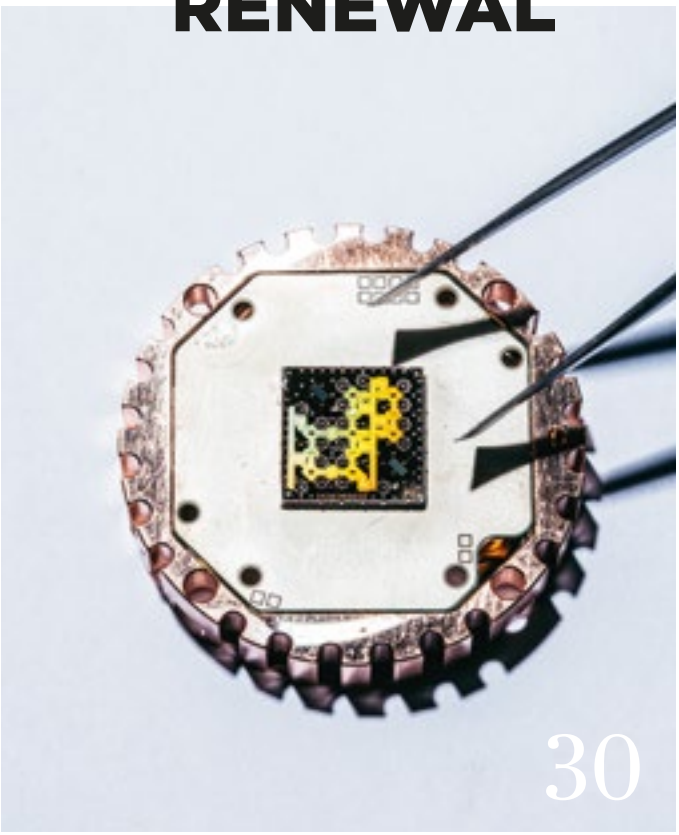
PHOTOS: *TÜV SÜD (Stepken); Alfred Steffen (portrait); Mattia Balsamini (microchip); Getty Images/ZimaNady_klgd (desert/back cover); AKI INOMATA/Courtesy Maho Kubota Gallery (cover)*

Standstill. Wanda's lead singer doesn't want to change anything.

Focus

RENEWAL



Change. Quantum computers can change everything.

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You can find even more articles on the ABOUT TRUST content hub. For instance, find out how desert regions could be re-greened using relatively simple measures.

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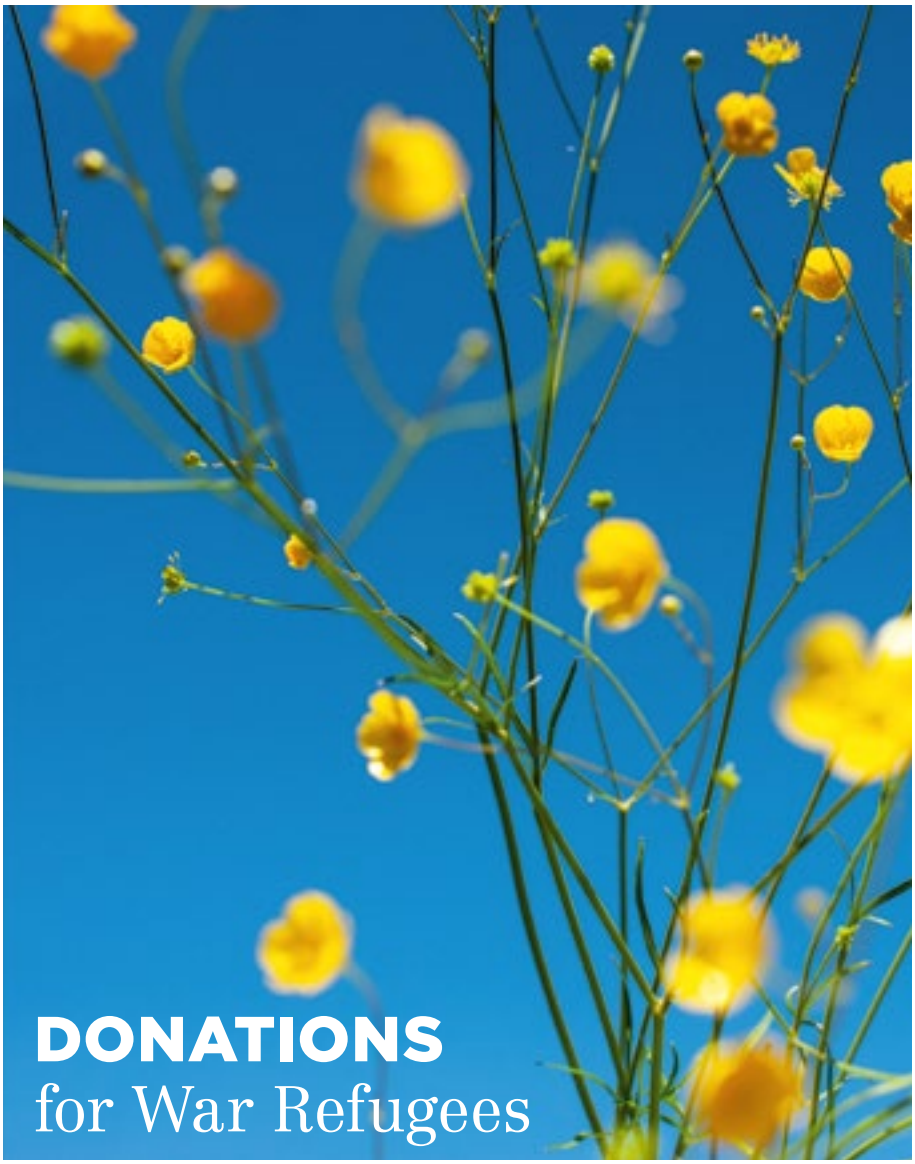

DONATIONS for War Refugees

Current events in and around Ukraine have also deeply affected TÜV SÜD employees. Numerous aid initiatives have been launched at various company locations in Germany and Central Eastern Europe. The company is demonstrating its solidarity with the people on site and the many refugees who have been forced to flee their homes—and is also providing direct assistance: 250,000 euros for humanitarian assistance were donated to the aid organization Save the Children in March. "We hope that this will bring a small ray of hope into the difficulties the children and their families are facing," said Chairman of the Board of Management of TÜV SÜD AG Prof. Axel Stepken. Save the Children provides practical assistance to refugee families. For example, children and their mothers receive toys, hygiene kits, diapers and protective face masks.

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PERCENT HIGHER

The capacities of cloud computing centers in Germany increased one-and-a-half times from 2016 to 2021. Their share of total capacity also grew from 20 to 33 percent, as shown in a recent study by the German federal association of the IT industry, Bitkom. By 2025, cloud computing centers could even comprise more than half of total capacity, while the development of conventional data centers is currently stagnating. This is in line with international surveys, which show, for example, that end-user spending on cloud infrastructure "as a service" will amount to around $122 billion in 2022. In 2015, the figure was just 16 billion US dollars. With increasing digitization, more and more companies are relying on the technology because of the advantages it has over traditional computing. Companies can save money because they don't have to buy, operate or maintain servers. Furthermore, cloud computing also allows companies to flexibly add software services as needed, which saves both time and money. The underlying system additionally reduces the risk of server failures, with all their associated consequences.

PHOTOS: Stocksy/Alexandra Stets (flowers); Getty Images/amphotora (cloud), Stocksy/Marc Tran (plastic bags); Virgin Hyperloop (Hyperloop)

RECYCLE ME!
Getting Started Sustainably

The circular economy is one of the great hopes for a more sustainable way of life around the globe (see the cover story starting on page 6). TÜV SÜD has now developed a new standard to help make packaging more environmentally friendly. Working with the company RecycleMe GmbH, the "Recyclability of Packaging" standard was developed to support manufacturers, bottlers, importers, online retailers, chain stores and other suppliers on their pathway to more sustainability. Testing and certification to the standard also takes into account regional collection and recycling infrastructure as well as the packaging's sortability. One core element is the creation of a digital twin of the packaging: a sort of digital analysis of the respective packaging based on documentation of the materials, weights and measurements while also considering all the relevant factors that influence the evaluation of recyclability. One major advantage of this digital technology is that optimization and solution potentials regarding a packaging's recyclability can be identified during the evaluation.

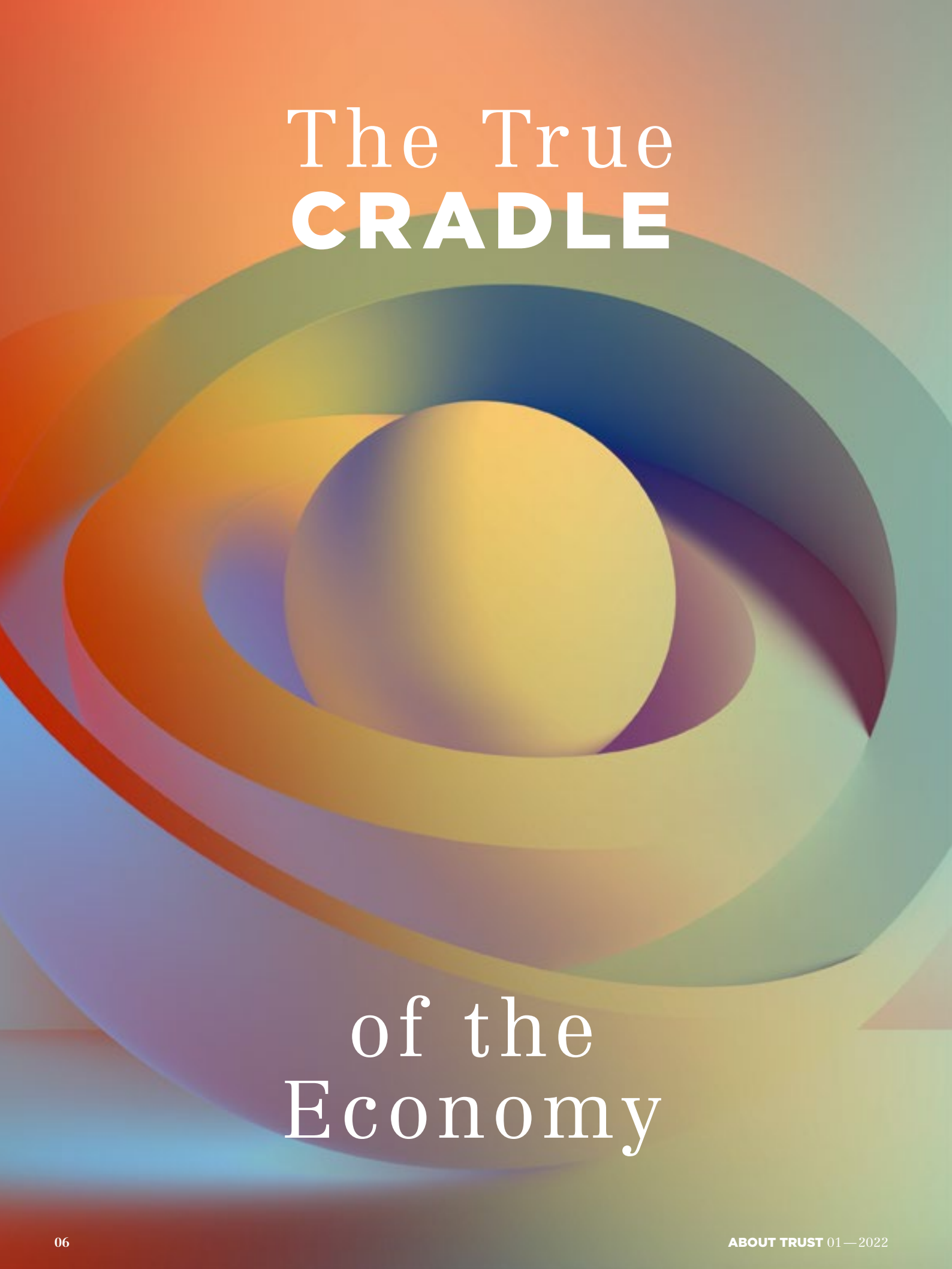
ROLLING STOCK

The vehicle fleets of the German Army and that of Deutsche Bahn Connect are two of the largest of their kinds in Germany. Both will be supplied and maintained across the board by TÜV companies: TÜV Nord, TÜV Rheinland and TÜV SÜD, along with TÜV Hessen, are forming a joint venture for this purpose. The contracts are expected to have a duration of seven years. Services to be provided include periodical technical inspections and emissions tests as well as damage and value appraisals, which will be carried out at TÜV SÜD's own service centers, at customers' sites and even abroad in some cases. Vehicles are already being appraised, since the start of 2022.

THREE TIMES FASTER
THAN THE SPEED OF SOUND

A type of train in a vacuum tube that can travel faster than 1,000 km/h—that's the idea behind the Hyperloop. A number of companies are currently planning to make this idea a reality, including across the sands of the Arabian Peninsula. Working with the company HyperloopTT, TÜV SÜD has defined the essential safety requirements for planning, building and operating such systems. The guidelines cover various issues—including the transport capsules, propulsion system, life-support system, the tubes and evacuations in emergencies—and can now be downloaded free of charge. At www.tuvsud.com/hyperloop-guideline there's a PDF with all the relevant information.

The True CRADLE of the Economy



The new world economy began symbolically on a day in April in the year 1956. The forward-thinking Malcom McLean had finally implemented his vision, and thus the completely remodeled ship "Ideal X" set sail that day, loaded with more than fifty rectangular boxes. At least that's how it must have looked to the dockworkers who were watching the ship from the jetty. After all, most cargo had previously been shipped in bales or sacks, but now everything was going to change: McLean had just founded the era of container shipping.

These containers proved ideal for the beginnings of globalization, which involved a number of other rapid developments: logistics prices fell dramatically, worldwide networking increased and, at the same time, humankind began consuming goods in a completely new way. Previously people had long been in the habit of repurposing things, repairing them or using them until they basically fell apart. For centuries, valuable materials were reused instead of just being thrown away, something archaeologists had discovered: the ancient world was a society of recyclers. For instance, glass was repeatedly melted down and reused, old clothing could be turned into paper, and the buildings of antiquity were quite naturally used as quarries for construction materials during the Middle Ages.

The boom in raw materials in the post-war period, with cheap crude oil, inexpensive coal and seemingly unlimited resources, brought unprecedented prosperity to much of the world. It also opened the floodgates—at least in the Western-oriented market economies—to a brave new world of consumerism. Now it made more economic sense to use a raw material only once instead of recycling it. The new mantra was: produce, use, discard.

THE NEED TO RETHINK

There have always been doubts about this economic approach. Fifty years ago, in 1972, the Club of Rome published a report titled *The Limits to Growth*. The book warned about the dangers of a society that was designed only for growth. The authors' warnings included the fact that raw materials would eventually run out just as damage to the environment would increase. The book received a great deal of attention, yet despite the oil-price shocks and awakening environmental awareness in the 1970s, the economy did not fundamentally change. The concept of restraint wasn't practicable in a world where there seemed to be absolutely no limits to growth—neither for companies nor for consumers. Growth continued its upward spiral with the help of increased productivity, research and development, as well as high-tech methods of exploration. It seemed as if there were actually no limits and that things could continue like this forever.

TEXT NILS WISCHMEYER

The circular economy is considered the visionary idea to make our way of life more sustainable. Scattered projects show what's possible, but why hasn't this economic system really taken off yet?

Until now, that is. As Henning Wilts from the Wuppertal Institute for the Climate, Environment and Energy explains, a storm has been brewing in recent years: "Firstly, the costs for raw materials are climbing, which can make it sensible to reuse them instead of always buying new ones. Secondly, it's becoming increasingly difficult to keep acquiring more and more resources. And, thirdly, in some societies there is pressure on companies to become more sustainable."

Companies thus face a dilemma: they cannot turn back time to the era before mass consumerism and globalization without causing the world economy to collapse. Pure abnegation is also not a solution, and definitely not an economically sensible one in a world economy that is designed for growth. At the same time, continuing the current economic model over the long run is also untenable. So how does this circle get squared?

THE BLUEPRINTS ALREADY EXIST

It's actually a blueprint that's been around for twenty years that could point the way to a future for business that combines all the seemingly conflicting goals: resource conservation, environmental relief and a continuing high degree of consumption and consumerism. Many established companies already have specific targets for it, others see great potential in it, and the chemical company Covestro (formerly Bayer MaterialScience), for example, plans to align its entire business model to it. The idea here is the circular economy in a globalized world. Instead of "produce, use and discard," products will be created that people buy, use and reuse for as long as possible, until, at the very end, the products or parts are returned to the economy, which will in turn manufacture new products from them.

"Cradle to cradle" is the name of this model, as described by the German chemist Michael Braungart and the American architect William McDonough in their eponymous bestseller. In the early 2000s, they outlined a new economic order with their modern version of the circular economy, one that could allow for resource-conserving consumption and an affluent society. To date, however, only 8.6 percent of all raw materials are recycled worldwide.

Why is that? A look at examples from three projects and industries shows that much is possible, but the obstacles remain numerous.

PHOTO: *Getty Images/wacomka (spheres)*

Project 1: A Building as a Raw Materials Storehouse

One person who truly believes in the circular economy and wants to prove its feasibility in architecture is Antonino Vultaggio. He's a senior partner at HPP Architects and in this role is overseeing the construction of one of the world's most modern office buildings. But can it even be called that? Asked about it, the architect smiles and talks instead about a raw materials "storehouse"—Düsseldorf's first office building using wood-hybrid construction, now under construction.

The construction industry is a prime example of an industry that could use a circular economy to make dramatic changes. New buildings around the world are one of the main consumers of raw materials such as sand and iron, as well as one of the biggest drivers of rising carbon dioxide emissions. The potential for savings would correspondingly be quite large. "But we've been thinking about this all wrong in the construction industry," Vultaggio says. "Buildings are only built once and the raw materials are never reused after that. We have to change that."

His current project, which is largely made of wood and carries the name The Cradle, is intended to show how things can be done differently. The firm reports that the construction of this building will produce less emissions compared to a more conventional office building. It is designed from the outset to ensure that the components are as durable as possible—but can do much, much more. The owner will be able to completely dismantle the building in a few decades, and a majority of its raw materials can be recycled because they've been selected for varietal purity and are toxin-free, as well as reversibly connected. For instance, the glass can be removed, melted back down and processed into new panes; the concrete, assuming it's in good condition, could find a new home in another building; and of course the main building element is wood, which has the most options for future use.

COMPANIES TAKE BACK THEIR RAW MATERIALS

The process is relatively simple: a company takes the current wooden components, disconnects them piece by piece, and replaces them with new ones. The old wood then gets returned to the original manufacturer, for example, where depending on its condition it can either be reused, reprocessed or utilized, via downcycling, for other wood products. The company Derix, which is supplying the wood for the façade, has already agreed to take back the materials at the end of the period of use and plans to reuse them for equivalent products, such as another façade. "After all, our building components are so durable that they can be used many decades after initial production," said Sales Director Markus Steppler at the Derix Group at the start of this new service. Due to the many imponderables, it won't be easy. For instance, it isn't possible to recertify or test the used parts because the standards for this haven't yet been developed. It also isn't possible to calculate the take-back price decades in advance since this can strongly depend on the wood's quality or the market situation at that point in the future.

> **"In this way we're removing the anonymity of the materials and giving them a value."**
>
> ANTONINO VULTAGGIO, PARTNER AT HPP ARCHITECTS

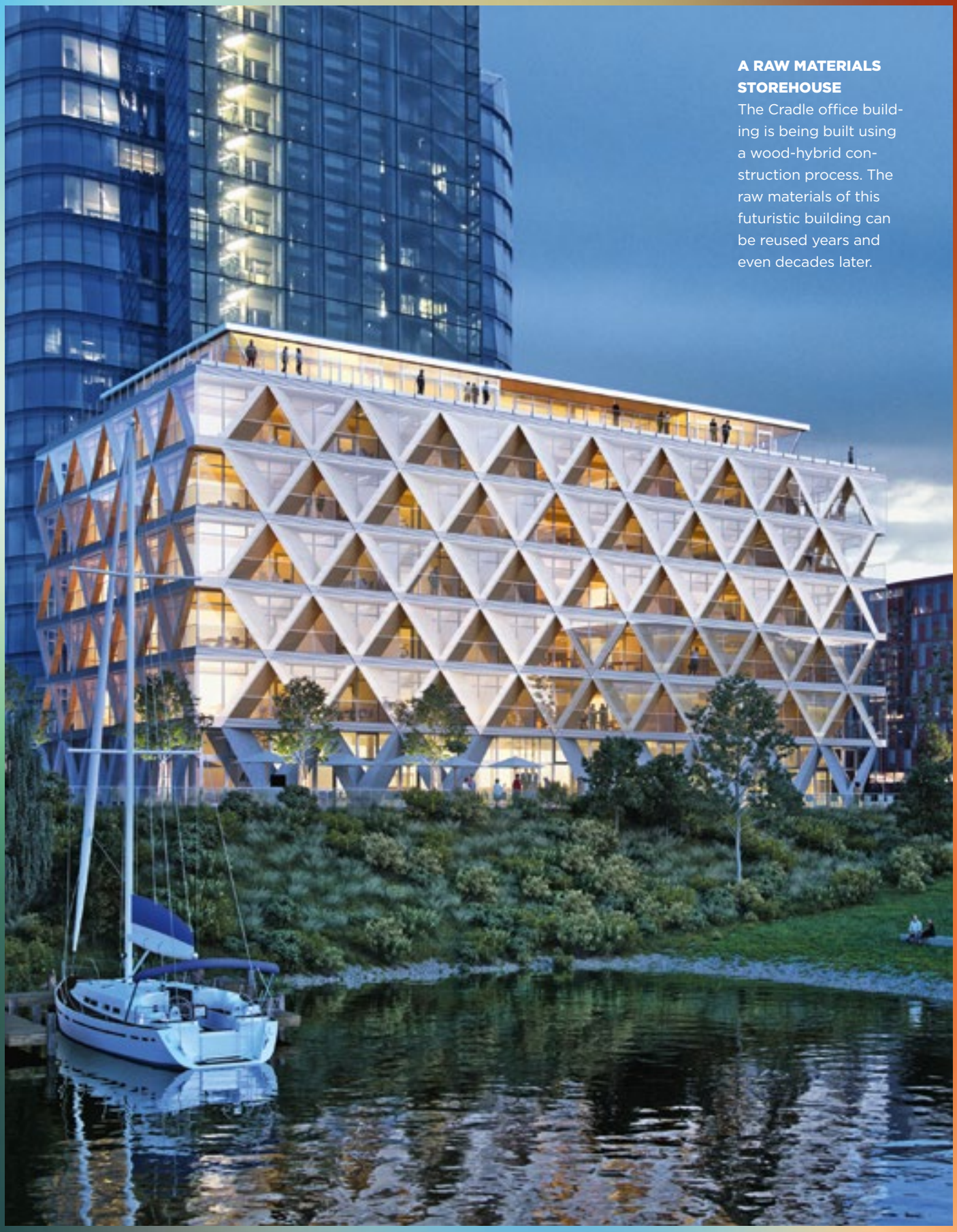
To make this new construction method possible, HPP Architects have designed the building so that the wood can be renewed cyclically. The components are designed according to the "design for disassembly" concept, meaning that the elements are held together with reversible connections. This allows wooden elements to be removed, piece by piece, without destroying them or leaving behind residues, such as adhesives. "For instance, the outer surfaces are usually replaced after seven to twelve years," Vultaggio says. Not because the surfaces wouldn't be intact, but because people want change. After 30 to 35 years comes the replacement of the façades, and then, after 80 to 100 years, the replacement of the building's shell.

This is also possible because The Cradle is working with what is known as a Material Passport. Much like a person's passport, this documents the most important characteristics of the products and materials, including their impact on human health, carbon dioxide footprint, dismantlability, sortability and recyclability. "In this way we're removing the anonymity of the materials and giving them a value," Vultaggio explains.

THE CONSTRUCTION INDUSTRY ISN'T REALIZING ITS FULL POTENTIAL

Using The Cradle as a model, there are three advantages right off the bat. Number 1: The construction produces less carbon dioxide, protecting the environment. Number 2: The building retains its value or may even increase in value, for instance if the prices for the raw materials used increase. And number 3: The company that takes back the building components has the advantage of being able to obtain raw materials more cheaply—or even at all—if they should become more expensive or rare in the future. Wilts from the Wuppertal Institute sees yet another clear advantage: "The companies become much less dependent on imports or purchases." All of this is important in helping make the circular economy a success. Without economic incentives, industries are unlikely to move in this direction.

PHOTOS: *Getty Images/Tabishere (gradient); HPP Architekten (The Cradle)*



A RAW MATERIALS STOREHOUSE
The Cradle office building is being built using a wood-hybrid construction process. The raw materials of this futuristic building can be reused years and even decades later.

However, Anette Müller believes there are more decisive factors holding back progress. She held the Chair of Building Materials Processing and Recycling at the Bauhaus University in Weimar, Germany, from 1995 to 2011 and is currently a staff member at the Weimar Institute of Applied Construction Research. She says that over the past several decades, policymakers have failed to set up an appropriate framework. For instance, this could include agreeing on standards for when what type of building material may or may not be reused for defined purposes. At the same time, there's been a lack of monetary incentives for the construction industry to address the issue.

The example of the construction industry shows not only some of the advantages but also a number of the obstacles to a modern circular economy. In a way, it's the problem of the chicken or the egg—if no company dares to become the trailblazer, the model will never work. At the same time, the initial investment costs will be extremely high for the pioneer. Moreover, there is no political framework to at least not make it unnecessarily difficult for companies to put their new ideas into practice. "Companies want a basic legal framework and policymakers are hoping the industry will do something and what we have is basically a stalemate," says Wilts, describing the dilemma. What's more, the whole idea will only work if it is considered internationally and across multiple industries. It won't work without the chemical industry on board, nor will it function without the construction industry and other manufacturing sectors. "And that of course is very difficult to coordinate, much like protecting the climate," Wilts says. Ultimately, however, he explains that there's only really one inconvenient solution: someone has to get the ball rolling.

PHOTOS: *Maxwell Ashford/Nikolai Frerichs*

FROM THE TOP
The RUEI-01 prototype has been designed so that a robot can completely disassemble it, piece by piece, with the help of digital instructions—without wasting any raw materials.

Project 2:
A Shoe That a Robot Can Disassemble

One person who wants to get the ball rolling is Maxwell Ashford. The designer has developed a concept shoe that fundamentally rethinks the traditional manufacturing process. Until now, used sneakers arrive at a facility without the staff or machines there knowing anything about their components. As Ashford explains, the shoes were simply shredded and the parts were then painstakingly sorted, leading to a large amount of waste. His RUEI-01 concept shoe is different, although at first glance, with its white sole, grey fabric surface and neon-yellow laces, it doesn't seem particularly distinct from any other trendy shoe worn around the world.

However, at second glance it's a fundamentally different product. From the very beginning, at the product development stage, the shoe was designed according to an important principle of the circular economy: to be easily recyclable in the first place. While most sneakers made today are held together with state-of-the-art adhesives and intended only for single use, the concept shoe is designed so that the components can easily be detached from one another later. Ashford's demonstration video shows how this works: a robot grabs the sneaker, scans the QR code printed on the tongue and thus obtains all the relevant information, including what materials have been used and how the shoe can be disassembled. With that information, the robot can take the neon-yellow laces and detach them from the shoe, followed by the tongue and then, piece by piece, the remaining components. The robot easily sorts the various materials into separate boxes. Afterwards, companies could put those materials back into their product cycles. This gives resources a longer useful life while maintaining quality and without having to use them for lower-quality products.

Modular construction methods make it easier to keep resources in circulation while maintaining quality.

PHOTOS: *Covestro (laboratory); Teresa van Dongen (foam cube)*

MIRACLE CURE
Two leading German chemists spent years researching an alternative polymer comprised of up to 20 percent carbon dioxide—a world sensation.

Project 3:
Carbon Dioxide as a Material for the Circular Economy

One person thinking about these types of ideas on an industrial scale is CEO Markus Steilemann of Covestro (formerly Bayer MaterialScience). He's been pledging to his employees for years that his corporation will adapt to the circular economy. Generally, the chemical industry as a whole plays an important part in any potential new business processes. Without their manufacturing processes or even chemical recycling, many modern materials can hardly be reused, particularly if they have complicated formulas.

According to the company Covestro, they've created 5,000 metric tons of production capacity for this novel polymer: the circular economy writ large.

Engineers at the company have therefore been working for years on new product solutions designed to recycle chemical compounds or waste materials. One of the most interesting results of this is cardyon. The company's product is a more sustainable alternative for polyurethane foams. This type of polyol is very popular for businesses because it's extremely flexible and also has some insulating properties. It can be used in mattresses, shoes and for individual packaging in supermarkets. The pivotal point in this is that until now, the carbon compounds used to produce it were obtained from crude oil, which is both resource-intensive and environmentally harmful.

Christoph Gürtler, director of catalytic research at Covestro, and Walter Leitner, director at the Max Planck Institute for Chemical Energy Conversion and professor at RWTH Aachen University, have spent years researching how to make polymers greener—and finally achieved a breakthrough. In a new process, they obtain carbon dioxide from an adjacent chemical plant, where the gas is a waste product. From there they pipe the carbon dioxide into a specially created production facility where it is combined with conventional carbon compounds.

The process works because the two scientists discovered a catalyst—a chemical substance that can trigger and control other reactions, acting as an intermediary between two substances, so to speak. In this case, they were searching for a substance that could enable inert carbon dioxide to become molecularly active enough to form chemical bonds without requiring the input of a great deal of energy. It wasn't easy, it was more like searching for the philosopher's stone. The ultimate result of their research is a type of white powder that makes it possible for the carbon dioxide to form new chains with conventional carbon compounds. This creates polyol, which is a precursor product of polyurethane foams. Carbon dioxide thus comprises 20 percent of the foam and, unlike many other pilot projects, the process is already being used on a large scale. According to information provided by Covestro, they have up to 5,000 metric tons of production capacity annually for this novel material. So the circular economy can work on a larger scale.

TÜV SÜD AND THE CIRCULAR ECONOMY
Sustainable textiles, recyclable packaging or electronic devices that are easy to repair: TÜV SÜD's latest online annual report addresses the company's integrated approach for supporting customers on the topic of the circular economy. Available online on May 5, 2022 at: annualreport.tuvsud.com.

“Reinventing yourself sometimes also means **FAILING**”

TEXT KATRIN BRAHNER **PHOTOS** ALFRED STEFFEN ——— He is the lead singer of the Austrian band Wanda and has become a star well beyond his home country: Michael Marco Fitzthum, better known by his alias Marco Wanda, talks about his own very personal secret for success, how fame has changed him forever—and what role change has played in all of this.

Mr. Fitzthum, reinventing yourself is a common part of show business. When was the last time you fundamentally changed something with Wanda?
FITZTHUM With our last album, *Ciao!*, we tried, against our own philosophy, to give ourselves a kind of new sound. I don't think it worked; I feel like that album went incredibly wrong. Nonetheless, it was important for us to take that path so that we could find our way back to what we really wanted to do—namely, play rock'n'roll.

What did you take away from the experience?
FITZTHUM Reinventing yourself sometime also means failing. But I'm a big fan of failing. We can learn from it and grow from it, it's simply part of life. If you've never failed you haven't really lived.

You'd already found the key to success at that point, you were stars. Why did you then decide to try something new?
FITZTHUM It came from the strange delusion of wanting to record the best album ever. It ultimately turned out to be our worst. I spent far too much time thinking about ways to reinvent our sound. We even changed the whole recording process for the album, it was insane.

In what way?
FITZTHUM We recorded the entire album in a giant house in the middle of nowhere in the Waldviertel region of Austria. It was quite a struggle. We thought that the forest might move something in us. Apparently what we actually need is the dust and street noise of our usual studio in Vienna. So this reinvention didn't work. The only thing we did learn is that we never want to do it again. Reinventing myself is now something that belongs more to my private life.

Well, the band reinvented itself at the beginning. At first you wrote lyrics in English, then in German. Then came your breakthrough. Is your success ultimately due to reinvention, in fact?
FITZTHUM When I started writing in German, it changed everything. I found my place among all the bands and musicians that were already there. With a huge bit of luck and a lot of very hard work, this reinvention did actually lead to success for me. Deciding to write lyrics in German was the best decision of my life.

What led to the decision?
FITZTHUM All the songs on the radio were in English, and they were only singing in English in every casting show. I didn't think that anybody was still interested in German lyrics. But in talking to people, I discovered the exact opposite: people want to hear songs sung in their mother tongue, in the language they use to think, dream and love. That's where I saw my chance.

So now the language for your music was set. How did Wanda come together from that?
FITZTHUM I co-founded the band with our guitarist, Manuel Christoph Poppe, over a beer in a bar. In the beginning, we spent a long time thinking about what we stood for and what we wanted to get across. I think that's very important at the start of a career. If you want to be successful, you need the right foundation from which you can grow. We initially also wanted our own trademark look,

like Falco with his slicked-back hair. Then we decided for our leather jackets. Language set, look set.

Was it a similar process for your sound?
FITZTHUM The sound came from a mixture of music that we like to listen to ourselves. We love blues, rock 'n' roll and Austrian pop music. Bands like The Beatles and Nirvana inspired us during our phase of discovery. I'm not a highly talented musician. I write songs with four to eight chords and that's it. But this limitation is exactly what makes our sound.

So you'd rather stay true to the old than seek out something new, for the most part?
FITZTHUM Instead of constantly reinventing ourselves, we'd rather focus on making what we can do even better. After all, we spent a lot of time finding ourselves as a band and finding our sound. We were really passionate and worked very hard forging the key that opened the door to success for us. And once that door is open, why should we start looking for a new key? Wanda may have come about through a reinvention, my decision to write lyrics in German, but now that we're successful with something that's fun for us, we prefer to move within the niche that we've created for ourselves.

Do you sometimes get bored with your music after so long?
FITZTHUM Not at all. Our sound and our songs are still incredibly fun. I'm just lucky that the music I like myself is also liked by so many other people. But if tomorrow I suddenly had the urge to try something completely new in a musical sense, I'd do it.

Even though your fans might be disappointed by it?
FITZTHUM I wouldn't recommend that anyone tailor their music to an audience's tastes. The audience can't become too important. That only makes you lose sight of yourself as an artist.

Your life as an artist has certainly changed from the ground up as a result of your sudden success. Is that a good change?
FITZTHUM The first three years in particular were crazy. Everyone wanted Wanda. We were on tour almost non-stop. There were times when we were almost scared that one of us wouldn't wake up. Despite the stress, touring life became a sort of addiction. A colorful circus where we all felt at home. Along with our gigs, everyday touring life was quite comfortable. You just drop a towel and someone else picks it up, you don't ever have to make your bed or iron your shirt, and food is always on the table. Coming home was a personal tragedy for each and every one of us. Everything seemed so pale afterwards. But you learn to deal with that over time.

Has success also changed you personally?
FITZTHUM Yes. For the first time ever, I can say that I'm really happy about my life. The band has given me a place in society and a task. Musicians like Kurt Cobain or John Lennon have always helped me get through tough times, and the idea that my voice now does the same for other people really moves me. If Wanda hadn't worked, I don't know if I'd still be alive today.

You're saying the band saved you?
FITZTHUM When I'm in front of a crowd of 12,000 people, I can't allow myself to feel any self-doubt. I've lost my fear of people through the concerts. I don't see them as a threat like I did before my career, but as potential. In the meantime, it's great fun to create something new together with others.

Before your big breakthrough, Wanda toured relatively unsuccessfully through disreputable bars. You must have had a lot of self-doubt back then.
FITZTHUM Those bars were small and rowdy, there was a lot of beer, a lot of stench, a lot of fights. We never felt comfortable in the underground. We had quit our jobs back then and put all of our eggs in the one basket. I think that's the only reason it worked.

How afraid are you of ending up back there one day?
FITZTHUM I've been living for years with the thought that it could all be over tomorrow. But that doesn't put pressure on me. We were declared dead from the very beginning and are still here. I meet a lot of people who really love what we do. That's why I believe that Wanda will never completely go under. And if people do get tired of us, then we'll just quit.

And then?
FITZTHUM Then I'll just have to reinvent myself. Do an apprenticeship as a chef or open an Italian restaurant. I'll think of something.

“Reinventing myself is now something that belongs more to my private life.”

Personalia

Michael Marco Fitzthum, alias Marco Michael Wanda, is the lead singer and lyricist of the Austrian rock band Wanda. In 2012 he co-founded the now five-member group together with guitarist Manuel Christoph Poppe. Two years later, their debut album Amore was a hit in Germany, Austria and Switzerland. One of their most successful hits is the song “Columbo”, which was released in 2017 on their second album “Niente”. Their trademark style is their leather jackets and a mix of rock beats and Viennese dialect. Their new album WANDA is being released on September 30, 2022.

PHOTOS: *Getty Images/Marina_Skoropadskaya*

Inside View

"From **DENTURES** to knees"

"Additive manufacturing (AM), or 3D printing, is a relatively new technology that has made major strides over the past ten to fifteen years and is now used in many industries. It has obvious advantages: compared to more conventional manufacturing processes such as casting or milling, there are practically no limits for the designs of AM products. Manufacturing can be decentralized—wherever a given machine is located—and one-off pieces are not a problem. These advantages also make this technology ideal for medical applications. AM processes usually involve metal, polymer or ceramic powders that are laid down layer by layer and fused with the help of high-energy laser beams; these can be used to create individually customized prostheses, implants or orthoses. From new dentures to artificial hip and knee joints, to splints for fractures or the complete replication of missing limbs, anything is possible.

Any medical product introduced to the market must comply with a strict set of regulations designed to ensure that products are effective and safe. This applies to all AM-produced products as well. Therefore it's particularly important that manufacturers pay attention to production quality. This starts with the right machines and materials, and ends with qualified employees. There's also a lot to consider when designing such a product: for instance, that it can be completely sterilized in every last nook and cranny. My team and I support manufacturers with training and continuing education programs and have put together comprehensive guidelines to help them meet the stringent quality requirements. A new QM ISO standard for AM will also be released this year, one that I helped write. Manufacturers will then be certified on the basis of the standard—all so that medical devices truly help people and enable them to live better lives."

SIMON SCHLAGINTWEIT
LEAD AUDITOR & MEDICAL EXPERT ADDITIVE MANUFACTURING AT TÜV SÜD

LIMITLESS TECHNOLOGY
Modern 3D printing has practically no limits. Polymers, ceramics or metals: these high-tech printers can reproduce every last detail of a medical device with pinpoint accuracy—and thus bring the technology of renewal to needy patients everywhere.

PHOTOS: TÜV SÜD (portrait); Getty Images/zoranm (3D printing)

Mending A Broken **HEART**

PHOTO: *Art Graphique & Patrimoine*

TEXT BIRGIT HOLZER —— When Notre-Dame Cathedral was struck by fire in 2019, the heart of France nearly went up in flames. The people with perhaps the most important role in its reconstruction are hard at work—and are tackling this mammoth project using modern technology.

With a mouse click, the virtual flight through the forest begins. However, the oaks in this stand of trees no longer soar skyward: they are extraordinarily robust roof beams. Delicate rays of sunlight shine around them. In this 3D film experience, viewers feel as if they themselves are floating among the oak beams, through centuries of history, through the heart of a country. The "forest" was what the historic beams of the Notre-Dame de Paris were called before they were destroyed by flames on the night of April 15 to 16, 2019. Since that fateful evening only these virtual images can provide an inkling of how special this place once was.

The fire at the Notre-Dame Cathedral, the construction of which dates back to the twelfth century, shook people well beyond Paris. Millions sat aghast in front of their television and computer screens and watched the inferno of flames and the smoke rising above one of Paris's most beloved landmarks. In the French capital, thousands gathered along the wide safety perimeter set up around the cathedral, which is truly the heart of the city. It is from the square in front of Notre-Dame that all distances to Paris are measured, from all over the world. On that terrible evening, many of the horrified onlookers began spontaneously singing. Some kneeled on the ground, their faces turned towards the burning cathedral.

It wasn't until the early morning hours that the firefighters managed to fully extinguish the blaze. Then French President Emmanuel Macron stepped in front of television cameras to record a speech that television stations broadcast around the country. "We are a nation of builders," Macron said in grave tones. "Yes, we will rebuild this cathedral even more beautifully, and I want it to be finished in five years. We can do it." It was a gigantic promise Macron made on that day. Repairing the heart of an entire country, and in just five years? And if so, how could it be done?

Even before Macron had spoken, one man had already sprung into action on an immensely important part of this task. That very night, Gaël Hamon and his team started searching the archives for existing photos and data from previous surveys of Notre-Dame. Just a short time later, Hamon received a call from the cathedral's prefect: "We need you," he was told, "and quickly."

GAËL HAMON, AGP CEO
Twenty-seven years ago, the trained stonemason founded the company *Art Graphique & Patrimoine* (AGP), which supplies the necessary technical data for restoring historic buildings. Previous projects include the Mont-Saint-Michel Abbey in Normandy, the Palace of Versailles, near Paris, and threatened heritage sites in Syria and Afghanistan. "The public interest in our work has never been as great as it's been since the fire at Notre-Dame," Hamon says.

FROM THE 13TH TO THE 18TH CENTURY

Shortly thereafter, Hamon and his team were inside the gutted cathedral. Using the techniques of lasergrammetry (laser scanning) and photogrammetry, they made hundreds of color scans of every surface, collecting around 50 billion data points. They mapped inaccessible areas with a drone. Then the photos, point clouds (3D masses of data points) and scans were processed and superimposed on one another. Using these images and current technical data, as well as those from before the fire that were found in the archive, the team used building information modeling (BIM) to prepare a precise model. In this digital process, all relevant information is fed into, combined and recorded in a synchronized database. The result is a three-dimensional model of Notre-Dame, a digital twin with all the dimensions and information about surfaces, materials and their current conditions.

The engineers quickly made the model available to other stakeholders, who have since decided to use it as the foundation for rebuilding Notre-Dame. What's more, the BIM model is dynamic, continually being updated and adjusted for every structural change on the construction site. Since the beginning, the model has evolved in step with the reconstruction process.

Now, almost three years later, Hamon, aged 51, is sitting in a modern screening room at his company *Art Graphique & Patrimoine* (AGP) in the suburb of Saint-Denis, north of Paris, and is clicking through the 3D model of the roof truss, which he simply calls the forest. "We were just in the thirteenth century, here we've now reached the eighteenth," he says, commenting on the images. "And you can see it quite clearly: the cut of the trunks is different; you can see steel screws and they no longer have the same shapes."

There's a photo hanging in this room, in black and white, that looks like an X-ray. It is of Notre-Dame's spire and timberwork, dating from

PHOTOS: *Art Graphique & Patrimoine*

DIGITAL MONUMENT

→ Experts have constructed a digital twin from billions of data points. This forms the foundation for rebuilding the cathedral.

↓ The spire, which collapsed during the fire, will be rebuilt using the digital data points.

↘ The entire cathedral was measured using laser scanners.

A DIGITAL CONSTRUCTION SITE IN PARALLEL TO THE PHYSICAL SITE

→ The photos used for the reconstruction will later be available to everyone. Thus, two cathedrals are created: one analog, one digital.

↓ Star photographer Yann Arthus-Bertrand is famous for his aerial photography. He provided his photos of Notre-Dame to help with its reconstruction.

when the architect Eugène Viollet-le-Duc had the spire rebuilt for the church in the nineteenth century. During the 2019 fire, this spire, which was located above the central nave, collapsed and plunged through the crossing. The blaze also destroyed the lead roof, the tower clock and parts of the ribbed vaults. There was also damage to some of the vault masonry, the roof gable wall between the west towers, the transept façades, two pipe organs, the choir stalls and rose windows from the nineteenth century.

A BUILDING RADIOLOGIST

For Hamon, this list of destruction is devastating. He recalls what he felt when he saw the live images of the flames blazing throughout the Gothic cathedral: "I was angry that it was happening. For eight hundred years, we had managed to leave the forest intact. And my generation is responsible burning it down." Investigations are still underway to determine the root cause of the disaster. What's clear is that there was a chain of unfortunate events, but probably also some negligence regarding safety precautions. "It took Notre-Dame going up in flames before people finally realized the fragility of our cultural assets," he says, clearly still upset about it.

He could speak for hours on the topic of restoration and historic site preservation, his great passion. Twenty-seven years ago, the trained stonemason founded AGP as a company specialized in digitizing the documentation of cultural heritage—high-tech for old treasures, so to speak. Today the company employs 33 people—architects, archaeologists, stonemasons, surveyors, art historians, computer graphic artists and software developers. Some of the tools AGP uses are laser scanners (lasergrammetry), which measure surfaces with laser beams, and the process of photogrammetry. The latter uses numerous photos of an object from different perspectives and distances, which are then run through a special software that generates a point cloud of data that is then used to create a digital twin. The company is particularly proud of having been awarded an EPV (*Entreprise du Patrimoine Vivant*), an "enterprise of living cultural heritage," by the state – the only company dealing with modern technologies to be recognized in this way. "Our métier is to contribute to the preservation and restoration of historic monuments and artworks, whether it's a prestigious building such as Notre-Dame or a small chapel in the countryside," Hamon explains.

Hamon likes to call himself a building radiologist because, like a doctor, he uses imaging techniques to patch things up—buildings, in his case. It isn't easy. One of the difficulties, he says, is that historic monuments have often been changed or become deformed over time, with some parts now irregular and no longer homogenous, and some even unique—while the modern software solutions and technologies were conceived for modern buildings and can't even capture certain deformations.

COMPANIES SUPPORT RECONSTRUCTION

There have been numerous changes in Notre-Dame over the centuries as well, with builders repeatedly reshaping the heart of the nation, a perfectly normal process at the time. Up until the nineteenth century, cathedrals were continually remodeled—evidence of this is Viollet-le-Duc's rebuilding of the spire, whose collapse during the fire prompted cries of dismay among the horrified onlookers. For special cases such as these, AGP works with beta testers for technology companies such as Autodesk and software manufacturers such as AutoCAD or Revit architecture, whose software is used for BIM or technical drawings.

All the work from the building radiologist Hamon has been added to data from other companies at the now digital construction site of Notre-Dame, which the French National Center for Scientific Research (*Centre national de la recherche scientifique*—CNRS) set up three months after the blaze. The startup Iconem, for instance, working with Microsoft, launched the "Open Notre-Dame" campaign to collect photos and images of the cathedral, one of the most photographed landmarks in the world. Renowned photographer Yann Arthus-Bertrand provided aerial photos he had taken. The French company Ubisoft did the same, supplying some of the thousands of photos they had taken to create the virtual backdrop for the video game *Assassin's Creed*.

ABOUT NOTRE-DAME

Notre-Dame is the cathedral of the archdiocese of Paris and one of the finest examples of French Gothic architecture.

1163

GROUNDBREAKING Under the reign of King Louis VII and by a decision of the Bishop of Paris Maurice de Sully, the cornerstone for the cathedral was laid.

1272

COMPLETION Notre-Dame was completed after more than a century of work—one of the largest Western cathedrals.

1793

RIOTING In the wake of the French Revolution, Notre-Dame was plundered, deprived of its religious function, and even used as a wine warehouse for a time.

1831

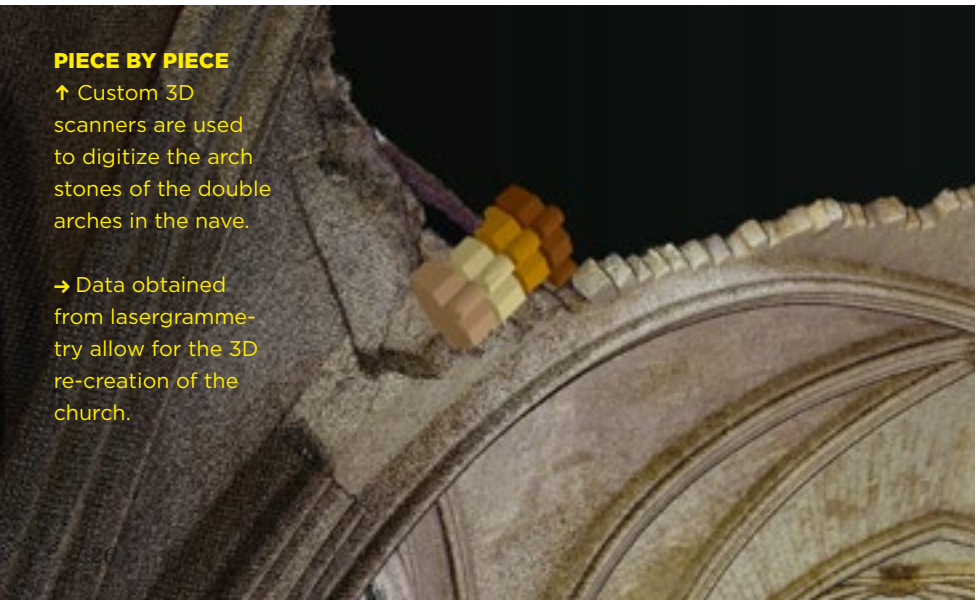
VICTOR HUGO TO THE RESCUE The national writer campaigned for the preservation of the building, threatened by decay and neglect, with his book *The Hunchback of Notre-Dame*. He inspired popular interest in the cathedral and funding was soon found.

1844

RESTORATION The architect Eugène Viollet-Le-Duc began a comprehensive renovation and restoration, including gargoyles, statues and the distinctive spire destroyed by the 2019 fire.

PHOTOS: *Iconem (collage); Yann Arthus-Bertrand (aerial photos)*

LIVIO DE LUCA, CNRS
The research director at the CNRS scientific center heads the online platform for the work on Notre-Dame. This type of "digital construction site" is unique around the world so far, he says: "Never have so many researchers from so many different fields mobilized for a joint project."



PIECE BY PIECE
↑ Custom 3D scanners are used to digitize the arch stones of the double arches in the nave.

→ Data obtained from lasergrammetry allow for the 3D re-creation of the church.

Another important data source was the work of American scientist Andrew Tallon, who had used laser scanners to collect billions of data points of the cathedral's façades and interior back in 2013.

PIONEERING WORK ON THE NOTRE-DAME PROJECT

All of this data has now been united under the wing of Livio De Luca. He's the director of the online platform, which can be accessed by the 175 researchers from a wide variety of disciplines who work at the CNRS, the French Ministry of Culture and also at universities based outside of France. Archaeologists, chemists, engineers, architects and others can all work in real-time. A digital ecosystem has been created that is unique the world over.

With the help of this platform, the actual physical construction site and the digital site are proceeding in parallel. A BIM model enables the ongoing sharing of all information, the modeling of different options and the validation of decisions. It's even possible to determine the exact placement for a crane or scaffolding without having to be onsite. This saves a lot of time, with the next phase of reconstruction set to begin soon.

Even when the heart has finally been rebuilt, the work of all the engineers and researchers will be preserved. Starting in 2024, it is planned to open the database to the whole world. Any company that wants to make a film or a video game from the information will be allowed to use the material. So in the end, perhaps there may also be a silver lining to the fire: Notre-Dame will soon exist in two copies, once again in analog and, thanks to clever minds like Hamon's, for the first time in a completely digital form.

PHOTOS: *Frédérique Plas (portrait) Chantier Scientifique Notre-Dame de Paris (3D scanner/3D models)*

Vision

TRANSFORMATION ARTIST

Thanks to a new technology, cars in the future will be able to change color at the push of a button—and thus save energy on air conditioning. The tech behind this comes from e-book readers, of all things.

In the gambling and entertainment city of Las Vegas, audiences flock to see famous magicians. So it seems par for the course when a large, angular car slowly changes from white to gray and then, finally, to black. But how does it do it? The SUV, which is on display at the annual CES trade show, is surrounded by amazed onlookers who want to see this magic close up.

Yet it isn't some fancy Las Vegas magic trick or illusion behind the vehicle, but rather real engineering work. At the CES in January 2022, car manufacturer BMW proudly presented its "BMW iX Flow featuring E Ink"—the world's first car that can change colors. So if the driver is in a dark mood, they can drive to work in a black car, or in a white one when they're feeling light and airy—warning their colleagues before they even step out of the vehicle.

This is made possible by the technology of the company's cooperation partner E-Ink, which is currently used in a similar form in e-book readers. Several million microcapsules are embedded into the surface coating of the car body. Each of the microcapsules contains positively charged black pigments and negatively charged white pigments. Depending on the polarity of the electrical field, either the black or the white pigments migrate to the upper side of the microcapsules—turning the car either black or white. No energy is needed to maintain the color, and it draws just a little current when the color changes.

The woman behind this technical magic trick is Stella Clarke. The project director and engineer explains the big advantage: light and dark colors absorb heat differently. On a hot sunny day, a white surface, which reflects light and heat, can prevent the car from heating up too much. Conversely, on cooler days, a dark-colored car can absorb more warmth from sunlight. "In both cases, a targeted color change means you can turn down the heat or the air-conditioning inside the vehicle," Clarke says. This saves energy—which means that, for an all-electric vehicle, changing the color could also increase the car's range.

Additionally, cars could use the e-ink technology to communicate with the outside world. In a snowstorm, cars could glow red to be more visible to other drivers, or, in the city, the color green could signal that a car-sharing vehicle is currently available.

There is further potential beyond the automobile industry, as well. This technology is already built into the majority of e-readers because it saves power. It can also be found in supermarkets, where it has replaced analog price tags on the shelves. Similarly, e-ink is sometimes used in bus and train stations, not to mention for art installations. Add colors to it and the possibilities seem almost limitless—for instance in smartphones. There are already a few smartphone models that use e-ink technology on secondary screens on the back of the phone. And when the models in Las Vegas start wearing e-ink clothing that magically changes colors on the catwalk, that will be a show worth betting on. Abracadabra indeed!

PHOTO: *BWM Group*

Filters Against **CLIM**

TEXT LARS-THORBEN NIGGEHOFF **ILLUSTRATION** SEÑOR SALME —— Combating climate change without "negative emissions" won't be possible. Emitted pollutants must be captured. One method is known as Direct Air Capture (DAC), and the recovered carbon dioxide can be useful in other areas over the long term.

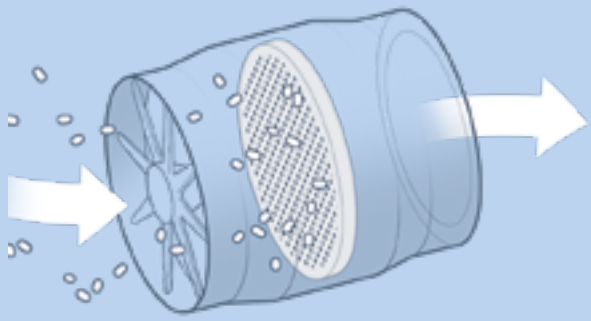
THE METHODS
DAC processes require huge fan blowers. These pull in air containing carbon dioxide, filter it and then expel it. There are two ways to capture the gas: amine scrubbing uses a solvent derived from ammonia that separates carbon dioxide out of the air. With carbon-dioxide absorption, a substance such as caustic soda reacts with the carbon dioxide to form a compound, which is then split to obtain pure the carbon dioxide.

THE PIONEERS
Companies around the world are working to make DAC viable on a large scale. Big pilot projects can be found in Switzerland, Iceland and in the United States, for example. Various manufacturers are also competing to offer the lowest price per extracted ton: this currently ranges from 90 to 250 euros, depending on the company.

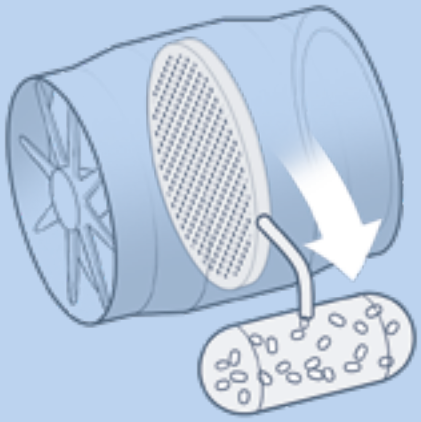
ATE CHANGE

CO_2 ABSORPTION

PHASE 1 ↓ CO_2 reacts with sodium hydroxide to form sodium carbonate.



PHASE 2 ↓ The sodium carbonate is heated to release pure CO_2. The CO_2 is then removed from the filter and collected.



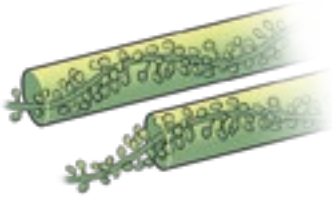
UNDERGROUND STORAGE ↑ After the filtering process, the carbon dioxide can be stored. This usually occurs in underground cavities known as saline aquifers, the pores of which are filled with salt water. Deep, non-degradable coal seams are also suitable for this storage.

CO_2 APPLICATIONS

Collected carbon dioxide can be used in various industries.

CONSTRUCTION MATERIALS Carbon dioxide can be mineralized into calcium carbonate, which can be used to manufacture concrete or asphalt. Furthermore, carbon dioxide can also replace water for mixing concrete.

LIQUID FUELS In simple terms, these fuels are made up of three parts: hydrogen, energy and carbon molecules such as carbon dioxide. For the fuels to be beneficial for the climate, the hydrogen used must be green hydrogen.



ALGAE Carbon dioxide can be used to fertilize algae. In turn, the algae can be used for foodstuffs, biofuel, plastics or carbon fiber. Algae also remove carbon dioxide from the atmosphere.

The **MAGIC**

TEXT LARS-THORBEN NIGGEHOFF **PHOTOS** MATTIA BALSAMINI —— A bit, or binary digit, has a single value: either 0 or 1. A qubit, or quantum bit, in contrast, can also assume the infinite number of states between 0 and 1 in a single moment—at least in theory. But how does a quantum computer actually work? Where and when will one be ready for use? And why did Einstein think quantum experiments were spooky?

of **QUANTA**

A bit, or binary digit, has a single value: either 0 or 1. A qubit, or quantum bit, in contrast, can also assume the infinite number of states between 0 and 1 in a single moment—at least in theory. But how does a quantum computer actually work? Where and when will one be ready for use? And why did Einstein think quantum experiments were spooky?

Very strange conditions prevail in the quantum world. A quantum (plural: quanta) is the minimum possible amount of any physical property, such as matter or energy. These smallest of particles ignore logic. They are simultaneously located in an infinite number of places and influence each other without being physically connected. Quantum mechanics goes beyond the limits of our imagination. Yet it's not science fiction, but rather the fundamental physical theory of the universe.

Quanta can help us rethink the digital world: for many years now, companies have been researching quantum computers, which would be capable of performing absolutely enormous tasks. For instance, directing rush-hour traffic so that there wouldn't be any traffic jams. Developing personalized medication specifically tailored to an individual patient. Analyzing the growth of a tumor so precisely that it can be effectively inhibited. Creating encryptions that are so secure that not even other quantum computers can crack them. Putting together climate models that accurately predict which measures against climate change will be effective and how effective they will be. In short, quantum computers start where conventional supercomputers reach their limits: when the quantities of data become too vast and their interdependencies too complex for current technology to handle.

The foundations of quantum physics emerged back in the early twentieth century. In the canon of theories, quantum physics is old hat and we encounter its laws in everyday technology all the time. Whether we're speaking about GPS systems or modern eye surgery, smartphone displays or CD players—these things wouldn't exist without quantum mechanics. However, there is one question that has long caused headaches: Is it possible to bring the quantum world to computing?

The very short answer as of now is, "Yes, but…." To learn more, it's worth giving Klaus Mainzer a call. The philosopher, physicist and mathematician has written a number of books about future technologies such as artificial intelligence and quantum computers, and is also a professor emeritus at the Technical University of Munich. In conversation, he begins his exploration of the quanta in the traditional digital world of bits and bytes. He describes conventional computers as "switch boxes," something he doesn't mean disparagingly at all, but simply as a description of how these computers are built: "In the chips there are huge numbers of switches that are set either to 0 or 1." These switches can be cleverly combined to form algorithms. Even today's most powerful supercomputers don't know more than the two states of 1 and 0: on or off.

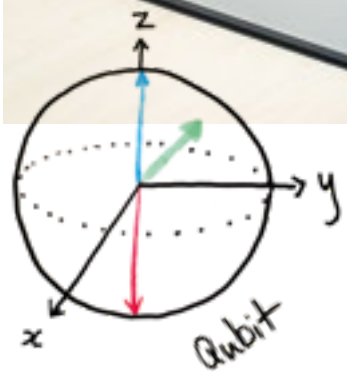
In contrast, a quantum computer works with qubits, or decision-making systems based on quantum theory. Qubits can also take on the state of 1 or 0, but also all other states in between. And not necessarily one after the other, but at the same time, in a single instant. Mainzer explains that it's a bit like a wall clock: "For traditional computers, the pointer is either up at the top at twelve, for 0, or pointing down at six, for 1. It's always jumping back and forth between these two states. In quantum computers, the hands are continuously wandering between the two states. These intermediate states indicate the probability that the value is closer to 0 or to 1. The superposition of all these possibilities between 0 and 1 is summarized in a quantum bit." Superposition is the term given to the ability for multiple states to exist at the same place and time.

SPOOKY ACTION AT A DISTANCE

Quantum particles possess a second remarkable property that Albert Einstein famously called "spooky action at a distance." To wit, take two photons and shoot them in opposite directions from a central source. Both hit screens along their path, where their respective states are measured. What's spooky about this is that although the two particles are physically separated, they still remain connected—or entangled, as it is called in quantum theory. So if you measure the state of one qubit, you then also know the values for the entangled one.

If we now combine the two properties of entanglement

FRAGILE EQUILIBRIUM
Researchers are attempting to influence the state of particles to create superpositions, for instance.

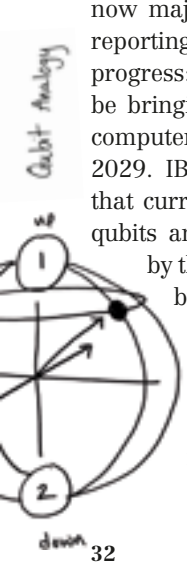


and superposition, we get an idea of how enormous the computing power of a quantum computer is: instead of making calculations with only the 1 or 0 values of a single bit, it can use the multiple values of multiple entangled qubits operating in parallel.

QUANTUM SYSTEMS ARE SENSITIVE

This is the theory of quantum computing. The practical use of qubit chips, however, remains difficult. The first problem is that quantum systems are very difficult to produce artificially. They require extremely low temperatures, like those of deep space, and the complicated cooling systems necessary to achieve this make quantum computers look like chandeliers constructed of pipes and wiring. The second problem arises when trying to read out the computational results, which are highly sensitive to even the most minor of disturbances. The output is a superposition of all possible computational results, and with their sensitivity to interference the output can quickly collapse onto itself. As Mainzer explains: "High-performance algorithms are thus needed to decode what the qubits have calculated." So while the potential of a quantum computer is absolutely enormous, tremendous efforts are also required to measure the results.

Developers have been fumbling their way forward, qubit by qubit, for the past few years, and now major tech corporations are reporting having made greater progress: Google announced it will be bringing commercial quantum computers to market starting in 2029. IBM has built a prototype that currently calculates with 127 qubits and hopes to achieve 400 by the end of 2022, and 1,000 by the end of 2023. One thousand is an important milestone, because quantum computers will only be better than common computers in solving a variety of problems simultaneously once they reach 1,000 qubits. So only at that point will the era of quantum superiority begin.

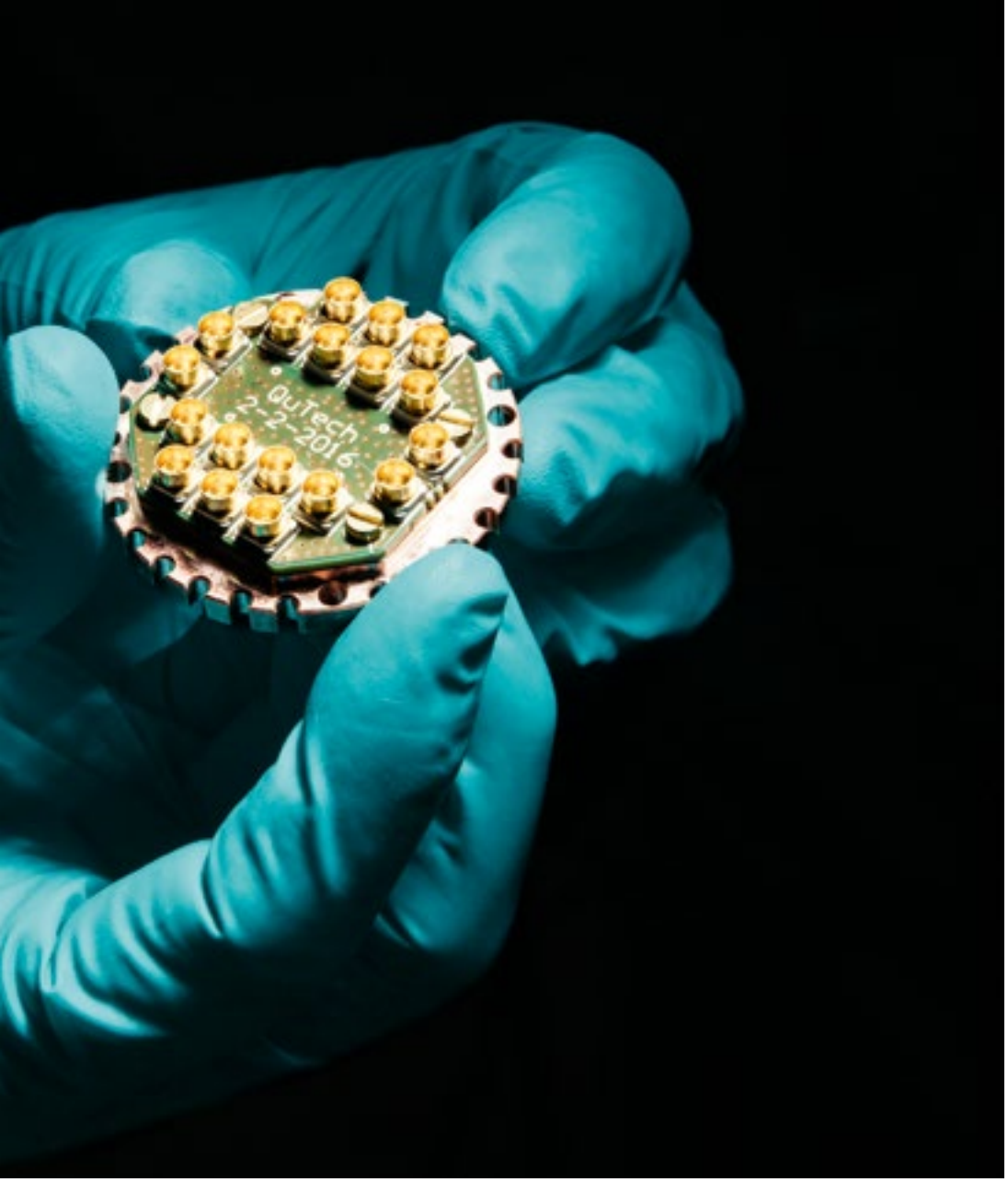


In China, on the other hand, the focus has been on developing a quantum internet, an effort joined by the Europeans in late 2021: a research alliance of the Fraunhofer Society and the Dutch research center QuTech is planning to develop a network of quantum computers in which entangled photons are sent through optical fibers. End-to-end security of transmission is guaranteed, because if a particle is captured or manipulated along the way, this is instantly detected by the change in the state of its entangled partner. This high-security network is already working for short distances, but the longer distances are creating problems because photons sometimes "get lost" along the way. So work is being done on the intermediate stations through which the information is passed on, much like a relay race. There is one question about the quantum internet that divides researchers: Is it worth the effort?

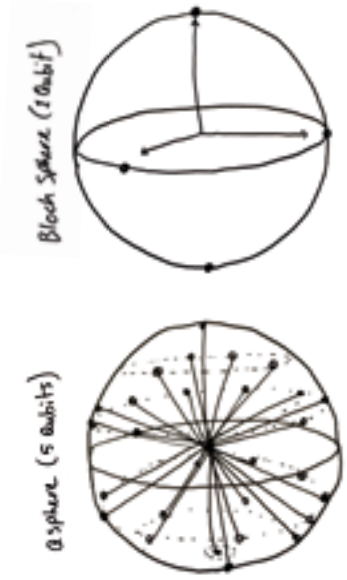
NEW POLYMERS, BETTER MEDICATIONS, LOW-RISK LOGISTICS

Potential areas of application for quantum computers in business are much more specific. In summer 2021, ten large German companies joined together to form the Quantum Technology & Application Consortium (QUTAC), with the aim of finding explicit applications for quantum computing. Among them is BASF, based in Ludwigshafen, Germany, which is looking for ways to use qubits to develop specialized catalysts to produce polymers for the chemical industry. It's a complex business trying to model them with regular supercomputers, which is why chemists have worked with approximations and simplifications to date. The idea is that quantum computers wouldn't require such compromises. The pharmaceutical company Boehringer Ingelheim is taking a similar approach, planning to use qubits to help develop medications. It currently takes an average of thirteen years for a new medication to receive approval. Quantum computers offer the potential to considerably shorten this timeframe. The multinational insurer Munich Re Group is taking aim at logistics: optimized and flexible routes calculated by quantum computers could help make supply chains much more robust in the face of disruptions. This would lower risks, naturally pleasing insurers.

So will quantum computers soon be found most everywhere? "No," says Mainzer. "If traditional mainframe computers are overwhelmed by a task, they will turn to quantum computers for the precise help they need." Mainzer imagines that a hybrid ecosystem of computers will emerge. It will help solve many problems, "but we still have to build and control the systems, not to mention checking the practical results ourselves."



THE QUANTUM RACE
Universities and companies are working on the first functional quantum computers. Meanwhile, corporate initiatives are exploring how quantum technology can be applied in the real world.



Just One Word

Ms. Verbeek, what do you think about…

R E S T O R A T I O N ?

Christina Verbeek, 52,
has been running the *Atelier für Restaurierung und Konservierung* (Atelier for Restoration and Conservation) in Cologne with her colleague Susanne Brinkmann for over twenty years. She also takes part in many restoration projects, including in Egypt, sometimes managing them. She's also been involved in a research project on the Cologne Cathedral. Verbeek studied restoration and conservation of art and cultural property at the Cologne University of Applied Sciences, with a specialization in wall painting and stone objects. During her studies, she was involved in research on petroglyphs in South America.

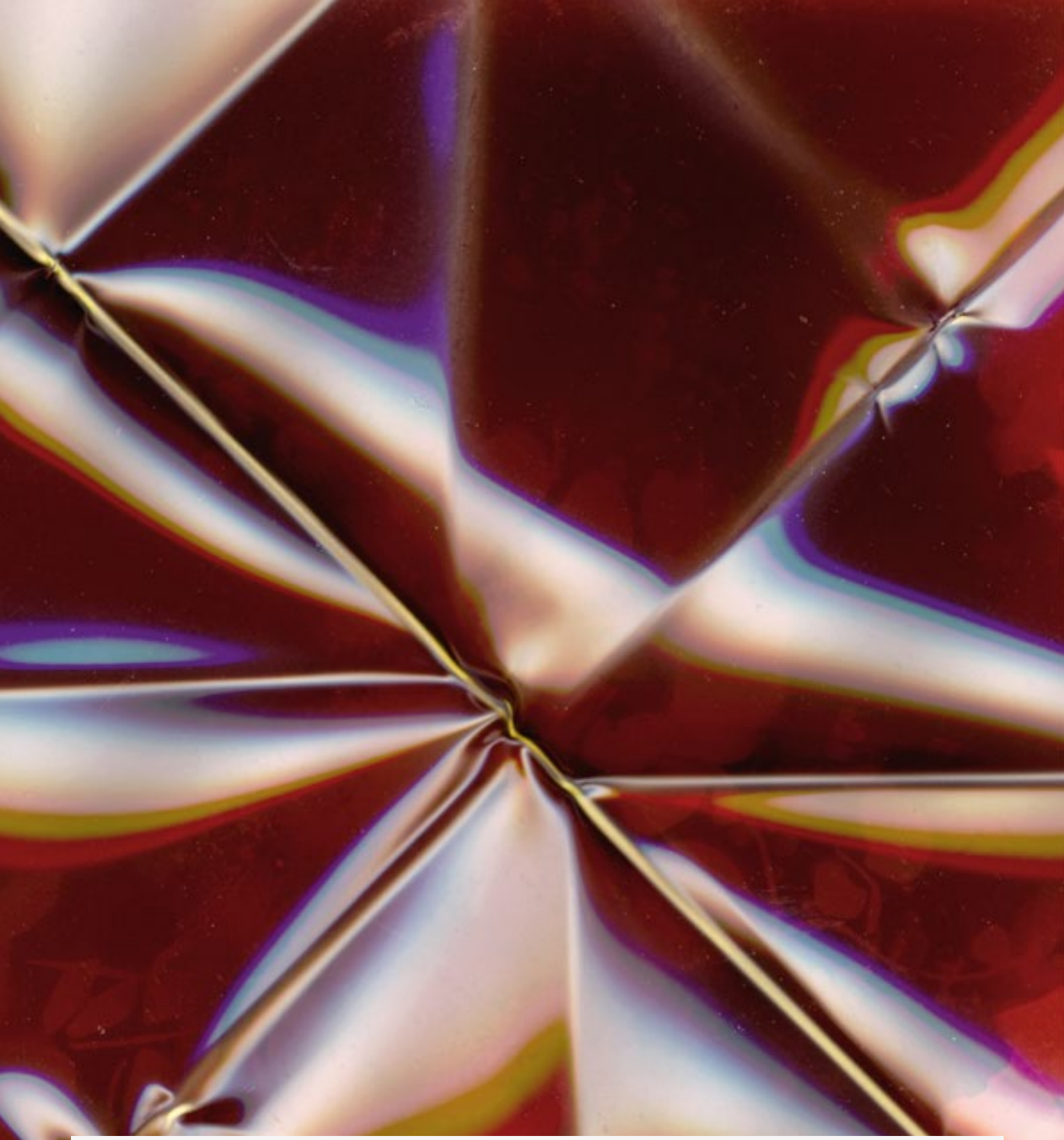
As an art conservator, I am always having to choose between conservation and restoration. Both are essential aspects of my work. How strongly I emphasize one or the other depends on the object in question. The material also plays a role. That's why we conservators choose a specialty at the beginning of our studies, for instance paintings, paper or textiles. I mainly deal with stone objects, mosaics and wall paintings. Unlike paintings, these usually can't be worked on in my studio, which is why I travel a lot.

My work has taken me to Egypt, for instance. Especially there, renovation would be a huge mistake. We're restoring a burial chamber in what is known as the Valley of the Nobles, near Luxor. We'd never grab a paintbrush to add to the wall paintings. Instead, the goal here is to preserve the actual condition for as long as possible. At most, we might cover up some deep flaws and holes. Otherwise we would disturb the object's soul and, as conservators, we want to let the work's soul shine through as much as possible.

For other works of art, we might also occasionally renovate some sections, but only after consulting with the preservation authorities and owners. Wall paintings in churches, which often have some liturgical meaning, are a good example of this. The point is that they should be understood. If I don't retouch the painting here and there, meaning in the areas where color is missing, I risk abandoning the painting to irrelevance. Even in these cases, I only work with the finest of brushstrokes, which can only be seen up close, to render the intervention understandable. The conservator never puts themselves before the artist.

The balancing act between preservation and renovation isn't always easy, especially since clients often have certain expectations that I can't necessarily fulfill. We can't work miracles. A colleague of mine liked to say, "You can't turn an old lady into a spring chicken." But that's not a bad thing. A certain patina is simply part and parcel of an object of art.

ILLUSTRATION: *Silke Werzinger;* PHOTO: *William Miller*



Picture This

What at first appears to be a close-up of a reddish-brown diamond is actually a piece of old, discarded color negative film. New York artist William Miller gave it a new life for his 2014 project "Surface Tension." He randomly crumpled up, cut and folded a hundred rolls of film from a scrapped photo project. With the assistance of a flat-bed scanner, he then photographed his works, capturing the abstract light refractions that emerged on the film surfaces. By destroying his old project, Miller deprived the rolls of film of their original purpose, allowing him to create something completely different: sculptural, mystical objects that fascinate viewers in a whole new way due to their unconventional repurposing.

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