Green gains

How sustainability is bringing ecology and the economy closer

Climate protection doesn't mean doing without. Recycling plastics saves money and benefits the environment. Sustainability will spawn a host of new business models.

By Janine van Ackeren / Photographs: Norman Konrad

Research for a healthier world: "People need to relearn how to live with nature," says Anita May. She works as a group manager at the Fraunhofer Center for Chemical-Biotechnological Processes CBP.

According to corporate consultants McKinsey, global production of plastics currently lies at 400 million metric tons a year. Of that total, little more 10 percent is recycled.

Germany tops the league in the use of plastics, accounting for 25 percent of the total consumption in Europe. And now Germany intends to play a leading role in the fight against plastic waste. Back at the beginning of 2019, 28 companies from the consumer goods and chemicals industries announced a joint campaign to combat this problem. It was around that time that the media began to fill with images of dolphins and seabirds choking to death on the plastic trash in our oceans. Over the period from 1950 to 2015, the plastics industry produced more than 8.3 billion metric tons – more than one ton for every person currently living on earth. In other words, the problem has never been more acute. Yet what technologies do we have to tackle it? Are they affordable? And, going forward, which new business models might we see emerge from the current sustainability debate?

Substitution

In early 2019, Porsche released a small production run of a couple of hundred vehicles – the Cayman GT4 Clubsport – featuring body parts made of natural fiber-reinforced composites. The Fraunhofer Institute for Wood Research, Wilhelm-Klauditz-Institut, WKI is working on new processes to replace fossil-based fibers in composites. "Lightweight parts for aircraft and upmarket automobiles use a lot of carbon fiber-reinforced plastics," explains Ole Hansen, research associate at Fraunhofer WKI. "Carbon fibers are light in weight and provide the necessary rigidity for body parts. But they are also expensive and require a lot of energy to produce. That's why we're using natural fibers such as wood, hemp, flax or jute, which also meet the specifications required for a vehicle door." In the case of the Porsche Cayman, that not only makes ecological sense but also brings sound economic benefits: it takes less energy both to produce natural fibers and also to recycle them at a later date. Moreover, once these natural fibers can be mass-produced, they should be significantly cheaper than carbon fiber.

Polymers made entirely of biobased materials – lactic acid, for example – are not yet able to compete on price with fossil-based polymers. In addition, it is important that these new biobased plastics can be produced with existing processing technology and that they are compatible with standard polymers and other materials.

Nonetheless, lucrative business opportunities are already emerging – especially for products such as children's toys and lunch boxes, where environmentally conscious consumers are opting for ecological alternatives to conventional items. "Changes to the political framework, such as a carbon tax or carbon trading, can also help tilt things further in favor of biobased polymers and pave the way for a broad commercial use," says Dr. Stephan Kabasci, departmental head at the Fraunhofer Institute for Environmental, Safety and Energy Technology UMSICHT. "All of these materials have a substantially smaller carbon footprint." The institute is therefore working on the development of biobased polymers to meet this demand. Current projects include polymers composed of biobased molecules that can be used as additives in adhesives or as biobased lubricants.

The problem of the higher price of biobased polymers disappears, however, when waste materials are used in combination with inexpensive processing methods. This is the goal of HyperBioCoat, an EU project now underway at the Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS. Researchers are using apple pomace as a feedstock to produce a biobased and biodegradable polymer material. Apple pomace is available in sufficient quantities and, as a waste material, inexpensive to source. What's more, its use as a plastics feedstock does not deprive the food industry of an otherwise useful commodity. The hemicellulose product extracted from the apple pomace is suitable for various purposes. These include coatings to provide a barrier against oxygen and water vapor; polymer films, trays and bottles; and natural waxes, paper additives and cosmetic articles. ▶

Natural fibers instead of carbon fiber: Ole Hansen, project manager at the Fraunhofer Institute for Wood Research, Wilhelm-Klauditz-Institut, WKI, is using wood, hemp, flax and jute to reinforce plastics – and save energy.


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A polymer with entirely new properties? "We've created a genuine alternative to anything currently available,"

says Dr. Michael Richter, Fraunhofer IGB

▶ In a similar project, researchers from the Fraunhofer Institute for Interfacial Engineering and Biotechnology IGB are likewise using waste materials as a polymer feedstock. Here, the basic idea is to endow biobased polymers with special characteristics by means of biomolecules displaying structural motifs that are not easy to achieve with petrochemical feedstocks. Given such characteristics, these polymers may then prove more attractive than petroleum-based products, despite costing more. In a joint project, researchers from Fraunhofer IGB and the Technical University of Munich have developed a new biobased family of polyamides using an industrially viable chemical transformation of naturally occurring terpenes. The resulting polyamides feature structural characteristics of the parent compounds. In place of a linear polymer chain, the process gives rise to a chain that contains a large number of small rings and other side groups. This endows the polymer with completely new properties. "We've created a genuine alternative, with clear distinguishing features, to anything currently available," says Dr. Michael Richter, head of the innovation field Bioinspired Chemistry at the Straubing branch of Fraunhofer IGB.

This process also has benefits from an industry perspective. Synthesis takes place in a single reaction vessel, which substantially reduces costs. It can be easily scaled up to large volumes and is therefore efficient. Furthermore, as a by-product of the pulp and paper industry, the feedstock – turpentine – is available in industrially relevant quantities. It makes most sense to replace fossil-based polymers in large-volume applications, where a lot of plastic is required. "We're currently looking at vegetable crates, for example; they weigh around two kilograms and contain a lot of plastic," says Christoph Habermann, research associate at Fraunhofer WKI. "And we're hoping to identify similar products in other sectors." Up to 30 percent of the plastic is replaced by wood fibers. This not only makes the material itself more environmentally compatible but also reduces the cost of raw materials by around 20 percent. A test run of 1000 vegetable crates has now been produced.

In the case of some applications, however, it is not as easy to replace the use of plastic with a biopolymer or another material. At the Fraunhofer Center for Chemical-Biotechnological Processes CBP in Leuna, a pilot plant is therefore producing so-called platform chemicals in a sustainable process based on bio-organisms. Conventionally, these bulk chemicals are produced from petroleum feedstocks on a huge scale. At present, 99 percent of all plastics are made from fossil-based feedstocks, with around 6 percent of global oil consumption attributable to plastics production. Fraunhofer CBP covers the entire process here: in the department for biomass fractionation, researchers use wood chips to produce the sugar required to feed bio-organisms; in the department for biotechnological processes, these bio-organisms are used to produce the required platform chemicals; and in the department for chemical processes, these platform chemicals are modified according to customer requirements. Concrete examples of this setup include the fermentative production of isobutene, a project for industrial partner Global Bioenergies (GBE). Here, a team 15 people working in shifts around the clock is operating a pilot plant to produce the platform chemical isobutene by means of a biotech process based on Escherichia coli bacteria. On the strength of the scientific results and process know-how accumulated during the pilot phase, GBE has long-term plans to build a plant for production on an industrial scale.

Recycling

Germans are big recyclers of plastic packaging. In 2017, however, more than half of this collected plastic packaging (61 percent) ended up in waste incineration plants, with a modest 39 percent being recycled. Moreover, genuine recycling remains very much the exception: only 15.6 percent of the collected recyclable waste found its way into new plastics, while 23.4 percent was used for so-called lower-grade applications. For a highly successful examples of recycling, we need look no further than the humble PET bottle, 98 percent of which are recycled. Inspired by this, a number of retail chains are now looking at introducing their own recycling systems for other types of plastic packaging. Bioplastics such as polylactide, for example, could be sorted and recycled to produce the same material.

The Fraunhofer Cluster of Excellence Circular Plastics Economy CCPE® pools the expertise of six Fraunhofer Institutes. Its job is to improve product design and increase recycling rates so as to make the production of plastics more circular. "A key aspect here is to organize a dialog between all the different stakeholders along the value chain," explains Dr. Hartmut Pflaum, who heads the central office for CCPE at Fraunhofer UMSICHT. "It's only by joining forces that we can accomplish this task." ▶

Are cars the only problem? Swiss environmental consultants ESU-services have investigated the carbon footprint of domestic animals. Perhaps it's time to say "neigh" to pets.

Keeping a horse generates CO_2 emissions of 3.1 metric tons a year. According to ESU-services, that corresponds to driving 9170 kilometers in a car. In fact, when all environmental impacts are included, the equivalent comes to 21,500 kilometers. By comparison, a car in Germany is driven, on average, some 13,000 kilometers a year.
© Illustration: Daniela Leitner

▶ Two of the cluster's six research departments are investigating the production of sustainable plastics. Projects here include the development of additives that cause the plastic to decompose as soon as it comes into contact with saltwater or other environmental elements.

Other research departments are focusing on recycling. For example, one group of researchers is investigating whether it is possible to digitally mark and map individual flows of plastic goods – i.e., to create a digital twin. In the case of a PC housing, for example, this would mean that a datafile created at the moment of production would be maintained throughout the entire product life cycle. Another group is looking at whether a "multicycle" plant might be used to recycle different types of plastic. Here, the most profitable business models are being identified and then scaled up. Parallel projects are examining whether, in terms of sustainability, recycling is necessarily better than one-way usage, and whether product recycling or chemical recycling is more effective. A Laboratory for Technical Biopolymers, to be established by Fraunhofer IGB in Straubing, will likewise focus on materials for a circular economy. In particular, it will concentrate on developing biobased polymers and identifying potential applications.

Up to 14 million parcels a day are delivered in Germany. Does all this cardboard really have to end up in recycling?

Fraunhofer CCPE® is also looking into what has become a huge issue in Germany and elsewhere – namely, the millions of packages delivered each working day. "Online retailers employ systematic processes," Pflaum explains. "As a rule, ordered goods are delivered in a box that, in most cases, ends up in the recycling container. Might it be possible to introduce reusable packaging? And, if so, what specifications would the system need to meet?" The research department for Business and Transformation markets new developments in this field and consults with stakeholders along the value chain, starting with industrial companies and progressing right down to individual consumers. For the industry, it's an idea whose time has come. "We've been approached by companies from right along the value chain," says Pflaum. "Polymer producers, packaging manufacturers, product distributors and retail chains."

With between 80 and 90 percent of all foodstuffs being wrapped for sale, it's little wonder that a large proportion of plastics – 40 percent, to be precise – is used in this way. Food packaging has to meet strict high requirements and often consists of multilayer laminated plastic film – a complex mix of different materials for which there is currently no suitable recycling process. That said, the CreaSolv® process from the Fraunhofer Institute for Process Engineering and Packaging IVV could offer a way out here. "We use a solvent mix tailored to the precise mix of plastics," explains Dr. Andreas Mäurer. "This is then filtered in order to remove any contaminants and unwanted additives." Here, researchers are focusing on a closed-loop approach, whereby the recycled material is able to assume the same function as before. "We've now been able to scale up our various business models to the point where we can recycle profitably." Examples include a demonstration plant built in Indonesia by Fraunhofer IVV, which is now recycling 3 metric tons a day of – previously nonrecyclable – multilayer plastic films of the type used for potato chip bags and wurst skins. With its powerful cleaning properties, the CreaSolv® process is also suitable for dealing with heavily contaminated plastic waste. This includes electronic scrap coated with flame retardant and expanded polystyrene used for building insulation. In an EU project, Fraunhofer IVV is currently building a recycling plant for expanded polystyrene with a capacity of 3000 metric tons a year. Similarly, a pilot plant in Bavaria is now recycling waste packaging collected from private households. In an initial phase, the plant will recycle several truckloads of waste a day.

Longer use

Increasing attention is now being devoted to closed-loop economies in areas other than plastics. As the saying goes: "Waste materials are simply raw materials in the wrong place." Closed-loop cycles of materials have a vital role to play in sustainable economic activity. "Here, we're focusing not only on the flow of materials but also, and most importantly, on the trio of ecology, economy and social acceptability," explains Dr. Andreas Stegmüller, research associate at the Fraunhofer Research Institution for Materials Recycling and Resource Strategies IWKS. This is a complex task. A car, for example, consists of thousands of individual parts, each of which is optimized to perform a specific function. "Viewed from the perspective of the circular economy, however, every part would have to be produced sustainably and contain no toxic materials et cetera. ▶

Caught between two stools? Dr. Hartmut Pflaum, head of the CCPE central office at Fraunhofer UMSICHT, is investigating the sustainability of child car seats as a potentially circular product.


ARBURG
THERMOLIFT

"Using a hydromechanical process, we can separate each component into its constituent materials to a purity of practically 100 percent."

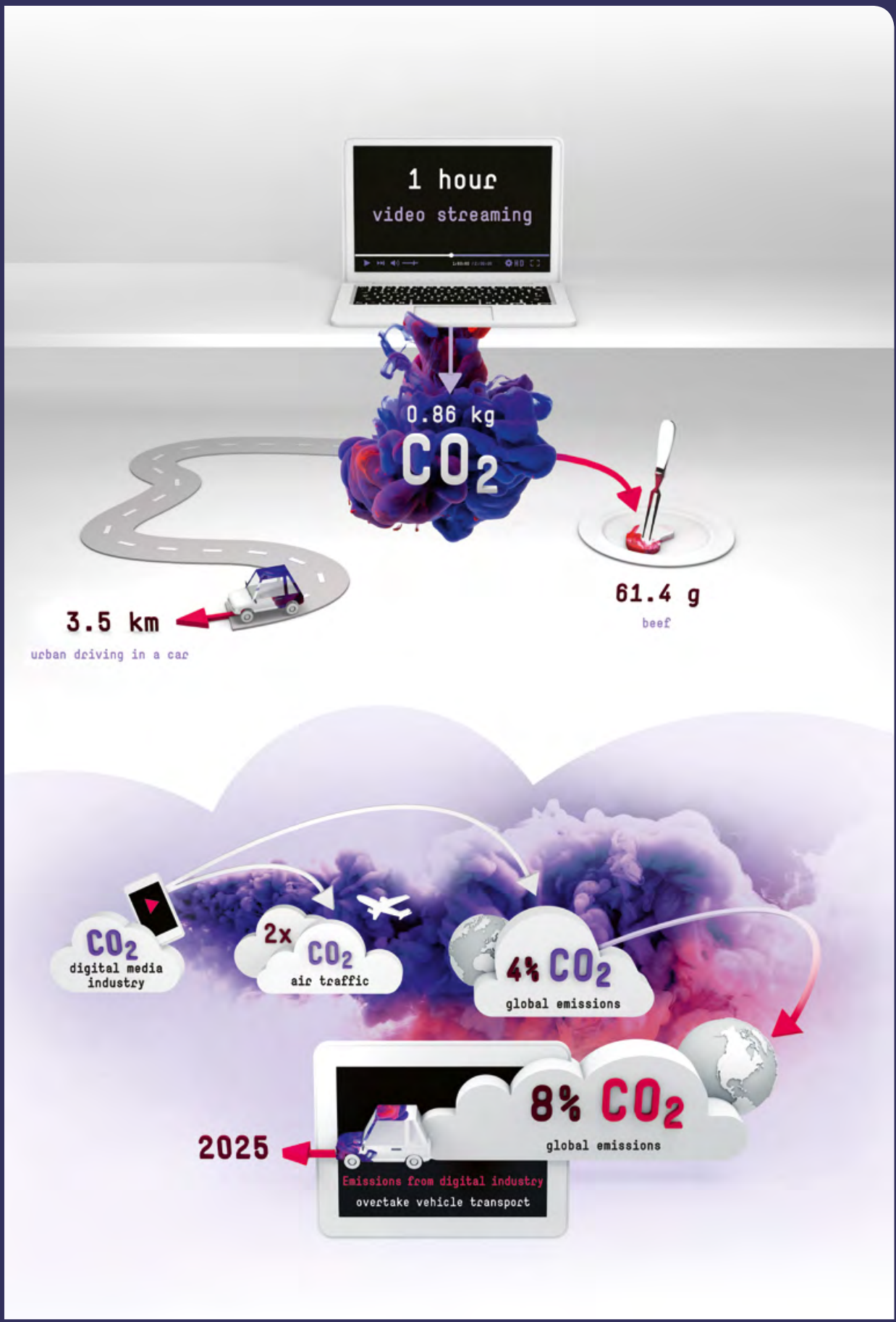
Dr. Jörg Zimmermann

▶ "Recycling, too, has to meet a whole bunch of technical requirements." In terms of today's automotive manufacturing, such conditions would be difficult to fulfill. However, the switch to electromobility offers a prime opportunity. Here, the industry is focusing on modular design, whereby individual components are connected to one another but can be easily exchanged. "We're putting together a unified concept that comprises materials, processes – both manufacturing and recycling – and the overall business model," Stegmüller explains. On behalf of industry, a research team devised a model to show the various options – classified according to profitability – for recycling electric vehicle batteries that no longer deliver the required performance. The project revealed that while conventional recycling of battery materials will yield a solid return, up to ten times as much can be earned by initially using the decommissioned batteries for localized storage of electricity generated from renewable sources. Battery performance is still adequate for this purpose, even if it no longer suffices to power an electric vehicle. However such a repurposing would require the establishment of an appropriate infrastructure. In other words, it would require a network of suppliers who would buy up the decommissioned batteries and then sell them on to, for example, private households to provide intermediate storage of excess electricity generated by photovoltaic panels. Here, too, the Fraunhofer researchers specified suitable business models. And, once again, the message was clear: Fortune favors the bold!

Life cycle

Companies can face major challenges when it comes to making an effective contribution to achieving greater sustainability. After all, a lot of work has already gone into making their manufacturing processes and high-tech products as efficient as possible in terms of materials and energy consumption. Yet appearances can be deceptive. As Michael Dieterle, research associate at the Fraunhofer Institute for Chemical Technology ICT, explains, looking at the problem in a new way can help reveal new potential. He is referring to the so-called life cycle gap – i.e., the difference between the energy and the raw materials that go into a product during manufacture and what can be extracted by means of recycling. Consider the lithium ion batteries used in electric vehicles. "In this case, there is a potential saving in carbon emissions of 45 percent," Dieterle explains. Simply recycling the battery casing would reduce the life cycle gap to 35 percent. Viewed over its entire life cycle, a battery's carbon footprint would shrink by 8 percent despite the additional work required to remove the casing for recycling.

A profitable prospect, in other words, not least with experts forecasting that the number of electric vehicles is set to rise to between two and three million by 2025. Promising recycling methods are also emerging for the battery innards, which are a rich source of valuable and, in some cases, strategic resources such as cobalt, lithium, nickel and copper, most of which have to be imported from counties outside the EU. Moreover, batteries also contain materials that pose a danger to health and the environment if not disposed of properly. In other words, battery recycling makes perfect sense from an economic and an ecological point of view. The problem is that batteries comprise a complex combination of composite materials. At present, therefore, they are either mechanically shredded or processed pyrometallurgically. In the former case, material purity lies at around 70 to 80 percent, since the shredding process merely reduces the battery to smaller pieces that may well consist of two or more different materials, which in turn require substantial further processing. In the latter case, the batteries are heated in a process known as pyrometallurgical extraction, which yields high material purity but fails to recover all the recyclable materials. What's more, it is very energy-intensive. Researchers at Fraunhofer IWKS have therefore developed an alternative process. "We use a hydromechanical process to separate all the various components according to material type," Dr. Jörg Zimmermann explains. "For the anode and cathode materials, the degree of purity is over 99 percent, and it's practically 100 percent for materials such as aluminum foil, copper foil and stainless steel. Our process is considerably more selective than a purely mechanical process." ▶



The environmental impact of digitalization: an hour's video streaming is the same as driving 3.5 kilometers in the car

The digital media industry's carbon footprint is estimated to be twice that of global air traffic – and thereby makes up 4 percent of global carbon emissions. On current trends, it will be producing more greenhouse gases than total vehicle traffic by 2025.
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▶ The process works as follows: battery cells are placed in a water bath, where a pulse of high voltage creates a shock wave in the water. This attacks the weak points of the battery cells – i.e., at the joints where one material is bonded to another. Rather than being shredded, the cells are broken into their composite parts, which are sorted into fractions. The process already works on a lab scale, and the pilot plant is now to be modified by the end of 2020 to enable continuous operation.

Rental models

Do we really need to own everything we use, particularly the things we only need on an occasional basis? As the debate on sustainability evolves, it's a question more and more people are asking themselves. Well-established rental models already exist in the mobility sector – car sharing or the public hire of bicycles and electric scooters – and similar schemes are being contemplated for electric vehicle batteries. When it comes to clothing, however, it would mark a radically new departure. That's not to say that such a model wouldn't make sense. Studies by Greenpeace show that as much as 30 percent of all new clothing is never, or only ever very rarely, worn. It would therefore be good if such unnecessary purchases could be eliminated. In fact, new retail models are already emerging. The German chain Tchibo, for example, is now offering its own-brand clothing for hire rather than for sale. Behind the Tchibo Share concept is the company Relenda GmbH. Yet can a clothes rental scheme be both sustainable and economic, particularly given the logistical requirements and the small target group? Researchers from the Fraunhofer Institute for Systems and Innovation Research ISI are now investigating two of the business models currently operated by Relenda. The study forms part of the Wear2Share project, which is funded by Germany's Federal Ministry of Education and Research (BMBF). "We can already say that both of these rental models are economically viable, even if the costs of logistics and cleaning are high," says Dr. Johannes Schuler, project manager at Fraunhofer ISI. As for their sustainability, the researchers have not yet been able to arrive at a definitive answer – it all depends on the base conditions.

We rent cars, we rent e-scooters. Might rental models for clothing also work?

Smart manufacturing

Ensuring the right base conditions is also a vital factor in manufacturing. Take the German foundry business, which produces over five million parts and components a year. Here, energy costs account for around 25 percent of gross value added. The corollary of this is high carbon emissions, with the casting of aluminum and light-metal parts alone responsible for around a million metric tons of CO_2 a year. Here, too, there is room for improvement. As Marc Kujath, research associate at the Fraunhofer Institute for Factory Operation and Automation IFF, explains: "By using movable crucibles and switching from electricity to gas, we can make energy savings of 60 percent, which would correspond to a reduction in carbon emissions of up to 80 percent." This new approach has been developed together with partners in the ETAL project. Researchers from Fraunhofer IFF were responsible for mapping and modeling foundry processes. On the basis of these models, they can now determine for other foundries which approach is best suited to their needs.

With regard to "green" energy – here, too, there is big potential for savings. In the RELflex project, researchers from Fraunhofer IFF are looking at how companies can use photovoltaic and other renewable sources of energy to power their own production processes and thereby increase their operating efficiency, competitiveness and self-sufficiency. This would also enhance their business model, enabling them, for example, to raise the bar even further for green products and not only produce them with biobased materials but also use renewable energy to do so. Ultimately, the most efficient solution would be to integrate buffer storage areas into the production process, and then manufacture to stock when energy is in abundant supply.

As the growing trend towards organic and regional produce illustrates, more and more customers are now demanding sustainability not only for manufactured goods but also for the food on their plate. This is only one of a number of reasons why growers are having to adapt their way of working. Following several long dry summers and an extended period of drought, there is now a real fear that a lack of water is going to render traditional irrigation systems nonviable. ▶

Prof. Charli Kruse is director of the Fraunhofer Institute for Marine Biotechnology and Cell Technology EMB.