Link
www.mec.ed.tum.de/en/fml www.cec.cs.tum.de/?langen

Too Good to Go

Picture credit: Astrid Eckert/TUM

Waste is a valuable source of raw materials, say Prof. Magnus Fröhling and Prof. Johannes Fottner. In joint projects with TUM colleagues, they are investigating what solutions for a circular economy might look like, for example in the automotive industry. Their credo: It will only work properly with a holistic perspective and a multidisciplinary approach.

“In truth, we have known for 50 years that we need to do something,” says Johannes Fottner, referring to ‘The Limits to Growth’ – a world-renowned study published by the Club of Rome in 1972. Despite this, the UNEP International Resource Panel reported in 2019 that global consumption of natural resources has tripled since 1970. Sustainable stewardship of the Earth and its natural resources is imperative. Fottner, Professor of Materials Handling, Material Flow and Logistics at TUM, explains that this includes seeing waste not as rubbish but as a source of raw materials. “When we throw away products, we are wasting valuable resources,” he says. “Mobile phones and used cars contain raw materials like metals and rare-earth elements, often in higher concentrations than found in natural deposits.”

In addition to high extraction costs, the finite nature of resources, environmental pollution, increased CO_2 emissions and biodiversity loss, volatile commodity markets and fragile supply chains are further arguments for eschewing our current, linear economic system of “take, make, waste”. Shifting to a circular economy is particularly important for Germany, which has few natural reserves of strategically important raw materials. ▷

Gesamter Artikel (PDF, DE): www.tum.de/faszination-forschung

Kreislaufwirtschaft: Ressourcen schonen, nachhaltig Werte schaffen

D

Um den Verbrauch von Ressourcen, Emissionen und das Abfallaufkommen zu reduzieren und die Umwelt zu schützen, setzen die Forscherinnen und Forscher der TUM auf die Kreislaufwirtschaft. Das Konzept zielt auf das Schließen von Stoff- und Produktkreisläufen und die Nutzung regenerativer Energieträger. Inzwischen existiert mit CirculaTUM eine interne Austausch- und Aktionsplattform, die an der TUM Kompetenzen sowie interdisziplinäre Forschungsvorhaben fördert.

Koordiniert wird die Initiative von den Professoren Johannes Fottner (Logistik) und Magnus Fröhling (Circular Economy): „Wir müssen dafür sorgen, dass Kreislaufwirtschaft vernünftig umgesetzt wird, und zeigen, dass es wirtschaftlich möglich ist.“ Im Rahmen von Projekten mit der Industrie erforschen sie, welche technischen Verfahren der Bereich Logistik für eine Kreislaufwirtschaft entwickeln bzw. wie eine Kombination aus Ökobilanzierung und techno-ökonomischer Analyse aus Systemperspektive aussehen kann, um unterschiedliche Technologien vergleichen zu können. □

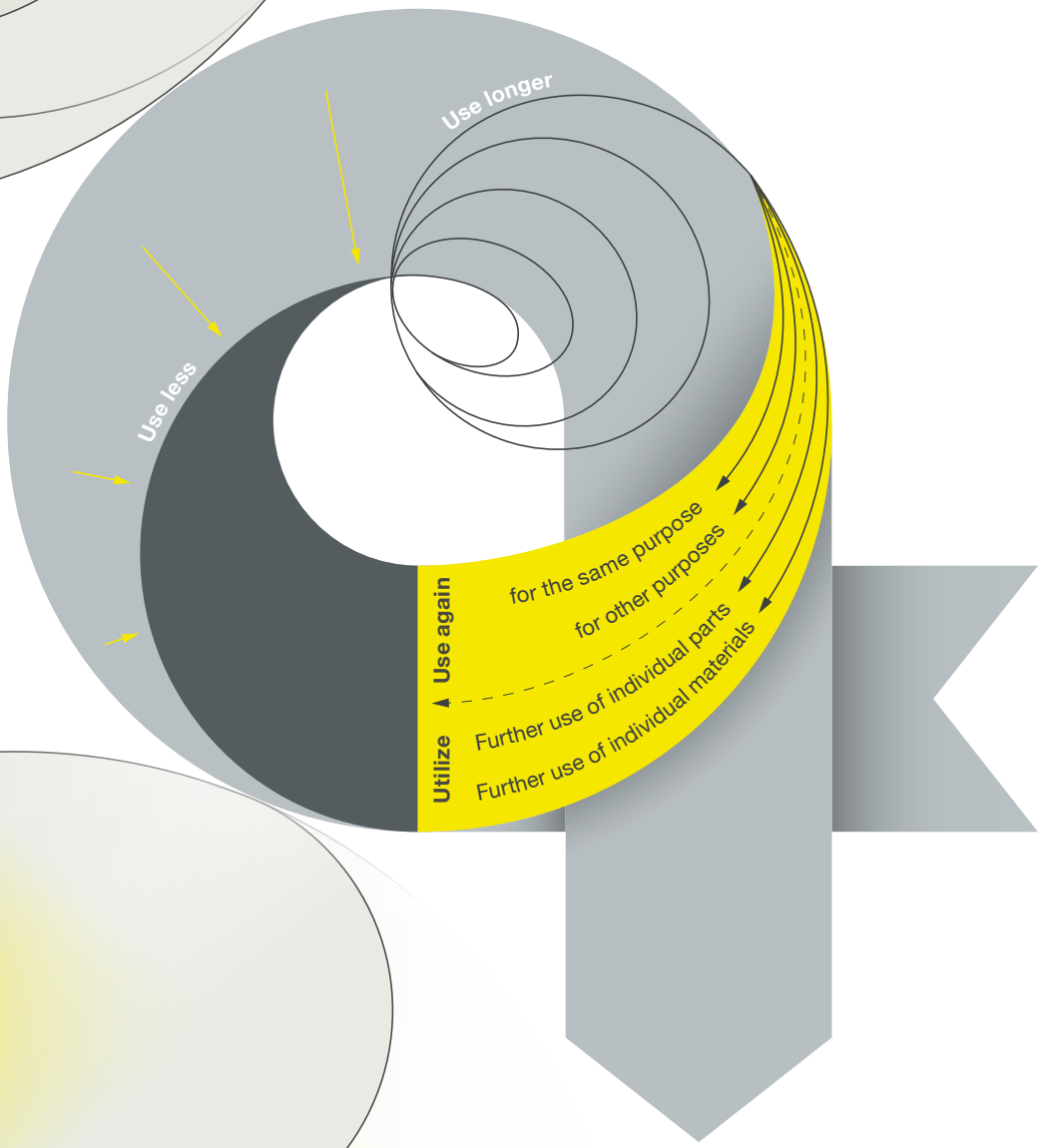
Picture credit: Astrid Eckert

“If we want to sustain a long-term livelihood on this planet … we need a fundamental, sustainable transformation.”

Magnus Fröhling

Prof. Magnus Fröhling

studied industrial engineering and management at the University of Karlsruhe, where he later earned his doctorate and habilitation. In 2015, he was appointed Professor of Business Administration, esp. Resource Management, at TU Bergakademie Freiberg. Three years later, he was appointed to the Professorship of Circular Economy at TUM’s Straubing Campus. Fröhling and his team develop concepts and methods to analyze, evaluate and optimize circular economy systems, looking at technologies, networks and industrial sectors. His work focuses on industrial value creation, the built environment and bioeconomy.



Circular strategies aim at narrowing, (use less), slowing (use longer), closing (use again) and utilizing material and energy flows.

“We can only exploit the circular economy’s full potential if we have adequate logistics solutions.”

Johannes Fottner

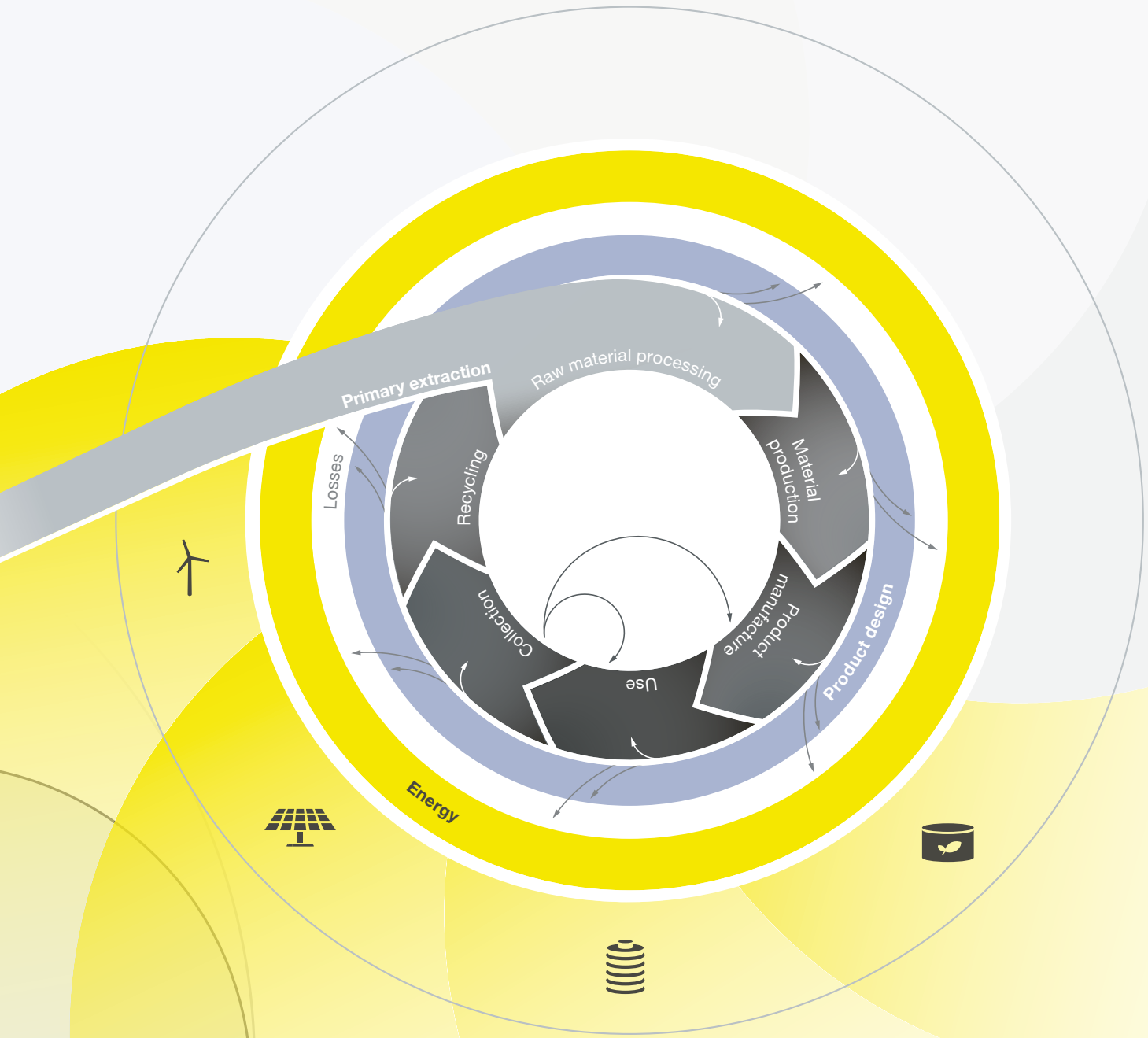
“If we want to sustain a long-term livelihood on this planet against the backdrop of a growing global population, we need a fundamental, sustainable transformation,” argues Magnus Fröhling, Professor for Circular Economy. The two TUM professors perceive the circular economy as the antithesis of the prevailing linear system. The concept involves closing material, resource and product cycles in order to prevent waste, conserve resources and drive forward efforts to protect the environment. But that’s not all: like the EU, which has established the circular economy in its Green Deal, the two researchers expect it to generate positive economic and social effects.

Circular strategies are designed to create sustainable material and product cycles. The aim is to use less material, extend products’ useful life, close material cycles through reuse and recycling, and regenerate natural systems, such as by using renewable energy sources and biodegradable, non-toxic materials. ▷

Prof. Johannes Fottner

studied mechanical engineering at TUM and received his doctorate in 2002. He then held a range of management positions at a Swiss company from 2002 to 2008 and moved on to the position of Managing Director of the Munich branch in 2008. In 2016, he was appointed Professor of Logistics Engineering at TUM. He now holds the Chair of Materials Handling, Material Flow and Logistics, which focuses on technical and physical aspects of logistics, including methods of controlling and optimizing material flows with innovative RFID technologies, using digital tools to improve logistics planning and the role of human input in logistics.

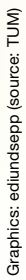
Picture credit: Astrid Eckert, graphics: ediundsepp (source: TUM)


Primary extraction
Raw material processing
Material production
Product manufacture
Use
Collection
Recycling
Losses
Product design
Energy

TUM Mission Network Circular Economy (CirculaTUM)

The platform for exchange and action, CirculaTUM, brings together the collective expertise within TUM across all locations and disciplines to promote teaching, research and innovation on the circular economy. Over 30 chairs and professorships and more than 100 researchers from various schools and locations are actively involved in the platform at present. This network is well aligned with the TUM Sustainable Futures Strategy 2030, which establishes sustainability as a vital, guiding value for TUM.

www.mission-networks.tum.de/en/circular-economy/home



Circular economy loop of a product.
Product design, energy use and losses are relevant for all product stages.

Graphics: ediundsepp (source: TUM)

Transforming production processes

Achieving this, however, will require the transformation of production processes. Simultaneously, business models will have to be completely reimagined. This might include leasing systems and rental models in which providing a product is part of the service, pithily known as “product-as-a-service” or “PaaS” models. “In this way, we can broadly uncouple economic development from demand for natural raw materials,” argue the two experts.

While potential solutions exist, Fottner and Fröhling believe that the problem lies in their implementation: the circular economy is highly complex and encompasses economic, environmental and social aspects. “At present, individual aspects are still considered in isolation. We need to instill a holistic, systematic mindset in decision-makers in business and politics. This starts with durable product design, continues through fabrication and use and then retaining products at the end of their useful life to collect their materials and return them to the product cycle. Consumers also need to change their thinking and believe that used, recycled products can have value,” explains Fröhling.

So, can Germany play a leading role in tackling what is notoriously a global problem? “We can’t always point the finger at others. Someone has to make a start. And, in the long term, it will yield economic benefits,” assert the researchers. They have also founded CirculaTUM, a transdisciplinary, TUM-wide network dedicated to the circular economy, with the aim of actively shaping the transformation both within the university and beyond. ▷

Logistics as a key success factor

The automotive industry is one sector in which both academics are active. The joint Car2Car project, for example, aims to extract and reuse high-quality materials from used vehicle components. “Automotive manufacturers have been optimizing their assembly processes for 100 years. The task now is to give thought to disassembly – looking at the entire life cycle – and then record and automate the resulting logistics processes,” comments Johannes Fottner. His specialist field has a vital role to play in the envisaged transformation, as he points out: “We can only exploit the circular economy’s full potential if we have adequate logistics solutions.”

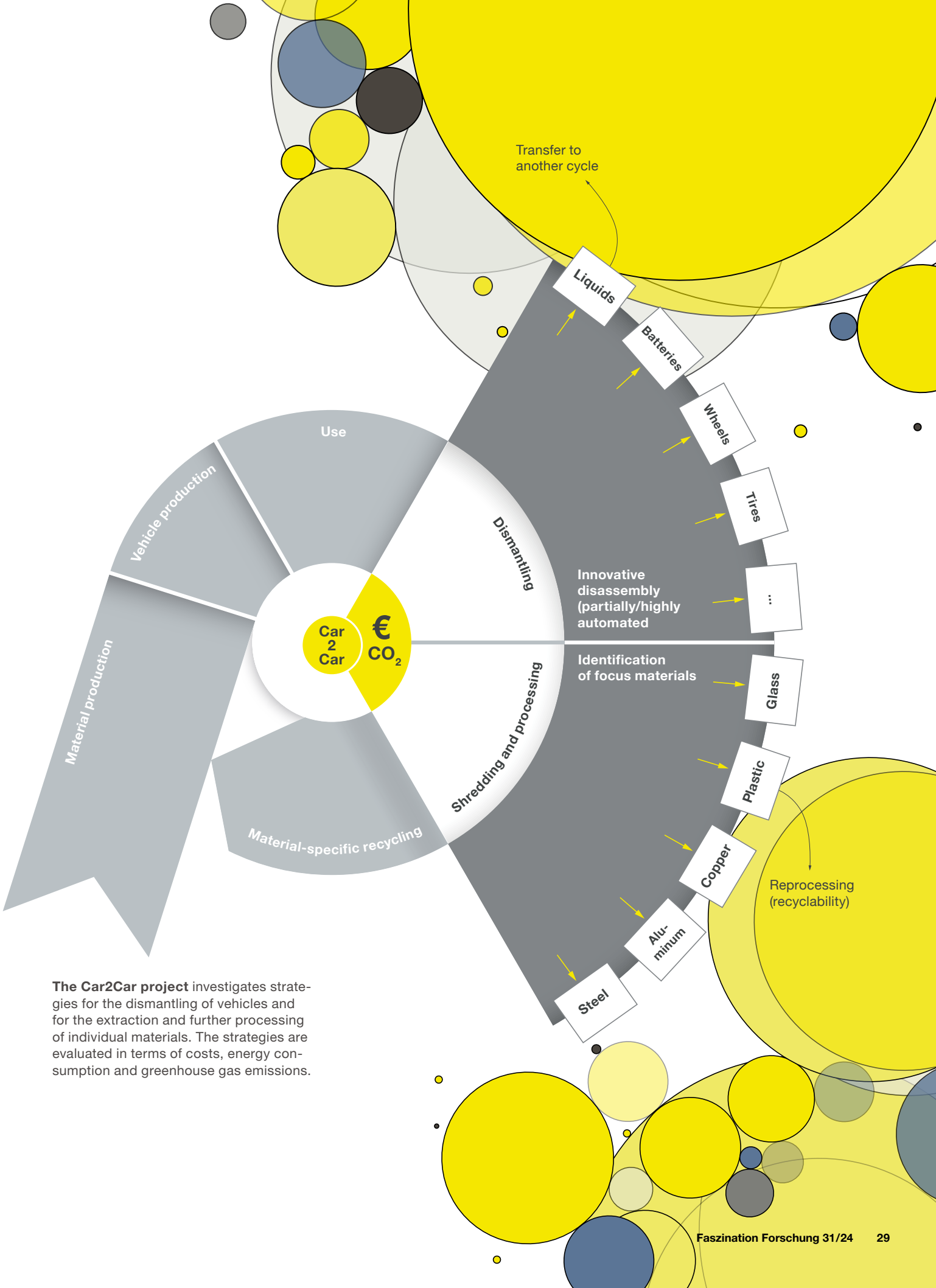
In essence, this will call for the end-to-end evaluation of supply chains, value chains and their associated processes. “This is where our professorship comes in. We’re developing methods to evaluate circular economy solutions,” says Fröhling. “This involves identifying and analyzing critical factors in their implementation. The question is: how and under what conditions can this succeed?” ▷

Car2Car: Innovative disassembly methods and automated sorting processes

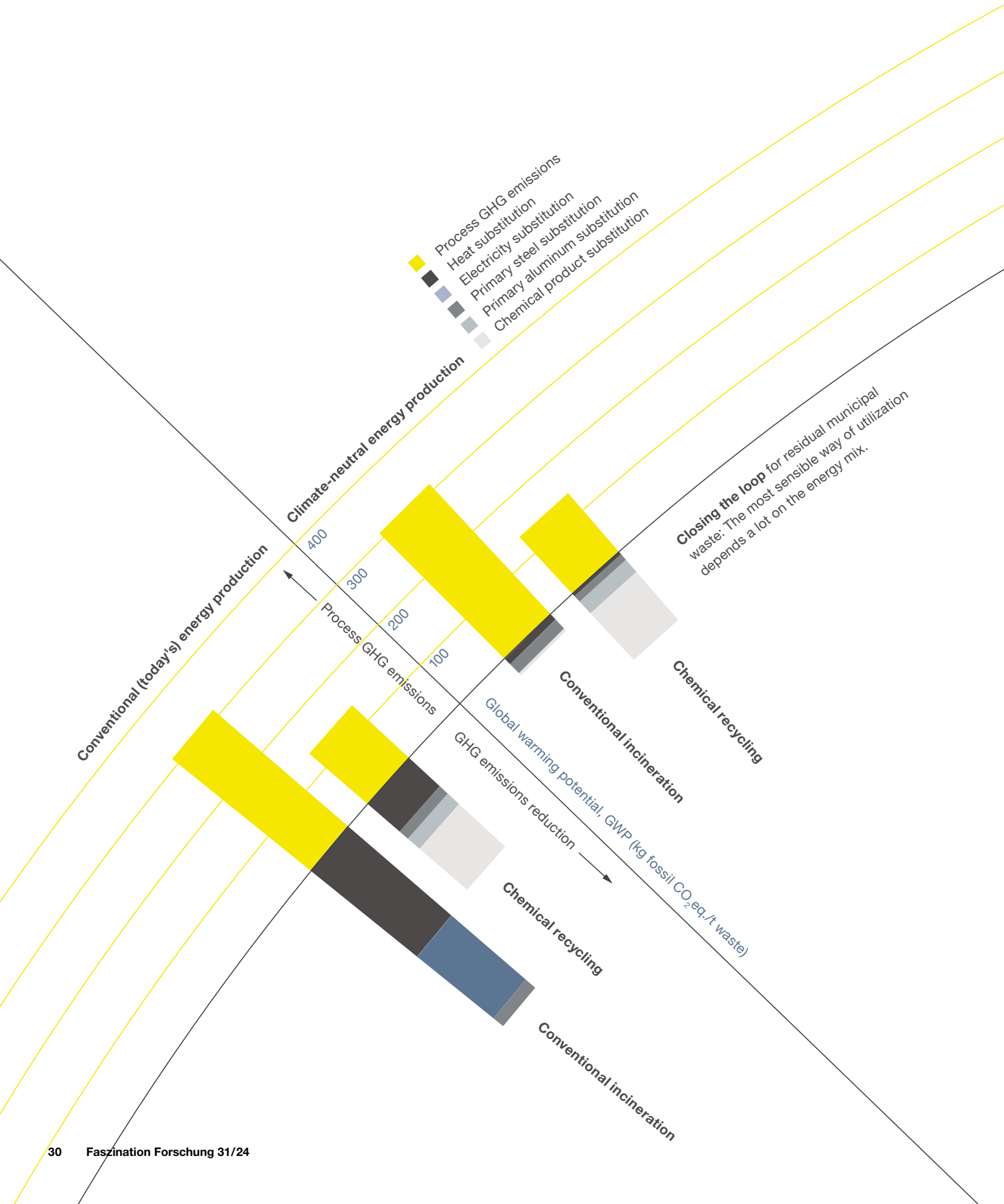
Launched in early 2023, the Car2Car project features a consortium of scientific institutions and industry partners – led by the automotive manufacturer BMW – working to close material cycles for automotive materials. The project participants are examining 500 used cars to find answers to questions about intelligent disassembly and methods of effectively and efficiently identifying, sorting and separating secondary materials (e.g. aluminum, copper and glass). This is because the components that can and should be disassembled depend on regulatory provisions, the materials’ structure and the amount of available materials. The aim is not only to improve the quality of secondary raw materials but also to increase the proportion of recycled materials in new cars. It also seeks to examine and evaluate the environmental and economic implications of closed material flows for selected groups of materials.

The task facing Johannes Fottner’s Chair of Materials Handling, Material Flow and Logistics and his colleague, Michael Zäh of the Institute for Machine Tools and Industrial Management, is to identify recyclable components and suitable technologies for dismantling them and sorting their materials. In addition to developing an optimized disassembly process, and after mapping the logistics processes involved, the success of the project depends on the researchers creating an economically viable and environmentally meaningful concept for recycling high-quality secondary materials. Magnus Fröhling and his team will assess the investigated processes and approaches. In addition, the researchers are investigating what the large-scale implementation of the solutions they find might look like, along with the potential positive environmental and economic effects. The German Federal Ministry for Economic Affairs has supported the research project with €6.4 million in funding.

Graphics: ediundsepp (source: TUM)



The Car2Car project investigates strategies for the dismantling of vehicles and for the extraction and further processing of individual materials. The strategies are evaluated in terms of costs, energy consumption and greenhouse gas emissions.


Process GHG emissions
Heat substitution
Electricity substitution
Primary steel substitution
Primary aluminum substitution
Chemical product substitution
Climate-neutral energy production
Conventional (today's) energy production
400
300
200
100
Process GHG emissions
Global warming potential, GWP (kg fossil CO_2 eq./t waste)
GHG emissions reduction
Conventional incineration
Chemical recycling
Chemical recycling
Conventional incineration
Closing the loop for residual municipal waste: The most sensible way of utilization depends a lot on the energy mix.

Chemical recycling as part of a circular economy

The Professorship of Circular Economy is examining the environmental and economic impacts of using solid waste to provide raw materials for the German and international chemical industry. In this context, the team combines approaches from life cycle assessment and technical, economic analyses to compare chemical recycling and conventional incineration systems for municipal waste in terms of their global warming potential and economic performance (capital investment, net present value, dynamic payback period and levelized cost of carbon abatement). The results show that, compared to conventional waste treatment methods, chemical recycling can contribute to reducing greenhouse gas emissions in low-emission energy systems and conserve natural resources. However, it is vital to create suitable framework conditions because the introduction of chemical recycling is associated with high initial system costs due to the capital-intensive nature of gasification technologies. This includes measures such as an obligation to trade CO_2 certificates for energy recovery as well as the introduction of a recycling quota to offset economic downsides.

Circular isn't necessarily sustainable

One of the focuses of Fröhling's research group is the role that chemical recycling can play in the circular economy: For example, they compare the global warming potential of domestic waste gasification with that of conventional waste incineration. Magnus Fröhling believes it is important to allocate the full costs of such processes to the relevant polluters. This also includes the external costs, which have primarily been borne by the community to date, rather than the polluters. "In relation to chemical recycling, we have also identified that fixed recycling quotas can be even more effective than tightening up emissions trading."

Even though the circular economy is a powerful concept, it should not be viewed as a panacea for all sustainability-related problems. The reasons for this lie in physical and economic limitations as well as human behavior. If, for example, cost savings lead consumers to increase their consumption of other goods, the benefits of the circular economy could quickly be diminished or even reversed. However, Fottner and Fröhling are convinced that this does not change the importance of the circular economy as a vital, fundamental element of the sustainable transformation of our economies and societies. ■

Eve Tsakiridou

More about sustainability at TUM:
www.tum.de/en/about-tum/goals-and-values/sustainability

Graphics: ediundsepp (source: TUM)