Circular Economy Strategy at RWTH Aachen University – A Raw Materials Perspective

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Abstract

Europas Wirtschaft kann derzeit als Recycling-Wirtschaft bezeichnet werden, in der man sich um die Sammlung von Produkten und Materialien nach ihrer Nutzungszeit und einem anschließenden Materialrecycling bemüht. Hierdurch soll die Deponierung vermieden und ökologische Risiken reduziert werden. Während dies beispielsweise für Stahl und Kupfer eine effektive Methode darstellt, da die beiden Werkstoffe hohe Sammel- und Recyclingquoten aufweisen, erschwert die zunehmende Rohstoffkomplexität technologischer Produkte die Herstellung hochwertiger Recyclingwerkstoffe zunehmend.

Um dieses Problem zu bewältigen strebt die Europäische Union eine Kreislaufwirtschaft an, die Materialkreisläufe auf mehreren Ebenen berücksichtigt: Überdenken des Produkteinsatzes und Intensivierung des Materialeinsatzes durch eine verlängerte Produktlebensdauer, Wiederverwendung, Wiederaufbereitung und Reparatur sowie der Kaskadennutzung; Reduzierung des Materialbedarfs in Produkten, mit Fokus auf Design für Kreislauffähigkeit und Vermeidung von Überspezialisierung; Recyceln von Abfallstoffen in der Wertschöpfungskette. Der Rohstoffindustrie kommt bei diesem gesellschaftlichen Wandel eine tragende Rolle zu, da sie als Anbieter von technischen Materialien eine Kreislaufgesellschaft erst ermöglicht.

Am Beispiel der E-Mobilität wird deutlich, dass die Herausforderungen, die sich aus der zunehmenden Materialkomplexität ergeben, nur durch konzertierte Anstrengungen aller Akteure entlang der Wertschöpfungskette bewältigt werden können: vom Anwender bis zur Industrie. Dies erfordert einen neuen, multidisziplinären Innovationsansatz, bei dem die industrielle Symbiose und zirkuläre Geschäftsmodelle stärker in den Fokus rücken. Zu diesem Zweck hat die RWTH Aachen ein Center for Circular Economy gegründet, in dem Akteure aus Forschung, Industrie, Gesellschaft und Politik zusammenarbeiten, um innovative Lösungen für zirkuläre Wertschöpfungsketten von morgen zu entwickeln.

Europe's economy can be called currently a recycling economy, where efforts are put on collection of end-of-life products and material recycling to reduce

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landfilling and ecological risks. While this has been an effective method for some materials like steel and copper, both having high collection and recycling rates, the increasing raw material complexity of technological products makes producing high quality recycled resources continuously more difficult.

To tackle this problem, the European Union engaged itself in a shift toward a Circular Economy, where material loops happen at several levels: Rethinking the consumption of products leading to the intensification of material use, through long products lifetime, reuse and repair service, as well as remanufacturing and cascading uses; Reducing the need for material in products, focusing on design for circularity and avoiding over-specialization; Recycling of end-of-life products as high-quality resource into the value-chain. The raw material industry has an important role to play in this societal transformation, as the provider of technical materials enable a circular society.

Using e-mobility as a case study, it appears evident that the challenges deriving from the increasing material complexity can only be tackled through concerted efforts by all actors along the value chain: from users to industrials. This necessitates a new multidisciplinary approach to innovation, with more focus put on industrial symbiosis and circular business models. To this end, RWTH Aachen University has created a Center for Circular Economy, where stakeholders from research, industry, society and politics can cooperate to find innovative solutions for tomorrow's circular value chains.

1. The Circular Economy: a new perspective for the European Union and Germany

The concept of Circular Economy is based on three simple principles, aiming to decouple economic growth from resource consumption: designing out waste, keeping materials in use, and regenerating natural systems. This can be achieved with the help of several material "loops" and "cascades", allowing for more efficient and intense material use. First, creating tight material loops, designing products for easy reuse, repair and manufacturing thus intensifying the use of raw materials and saving in labor and energy. Second, maximizing the number of times a product can go through these circles. Third, diversifying the possibilities for material reuse across the value chain, adapting the quality losses and material deterioration. And finally, keeping material streams as clean as possible to facilitate collection and recycling. These concepts are illustrated in the so-called Circular Economy Butterfly (Figure 1) diagram which highlights how a circular concept can both save raw material and create new business opportunities, especially in the raw material sector. [1] [2]

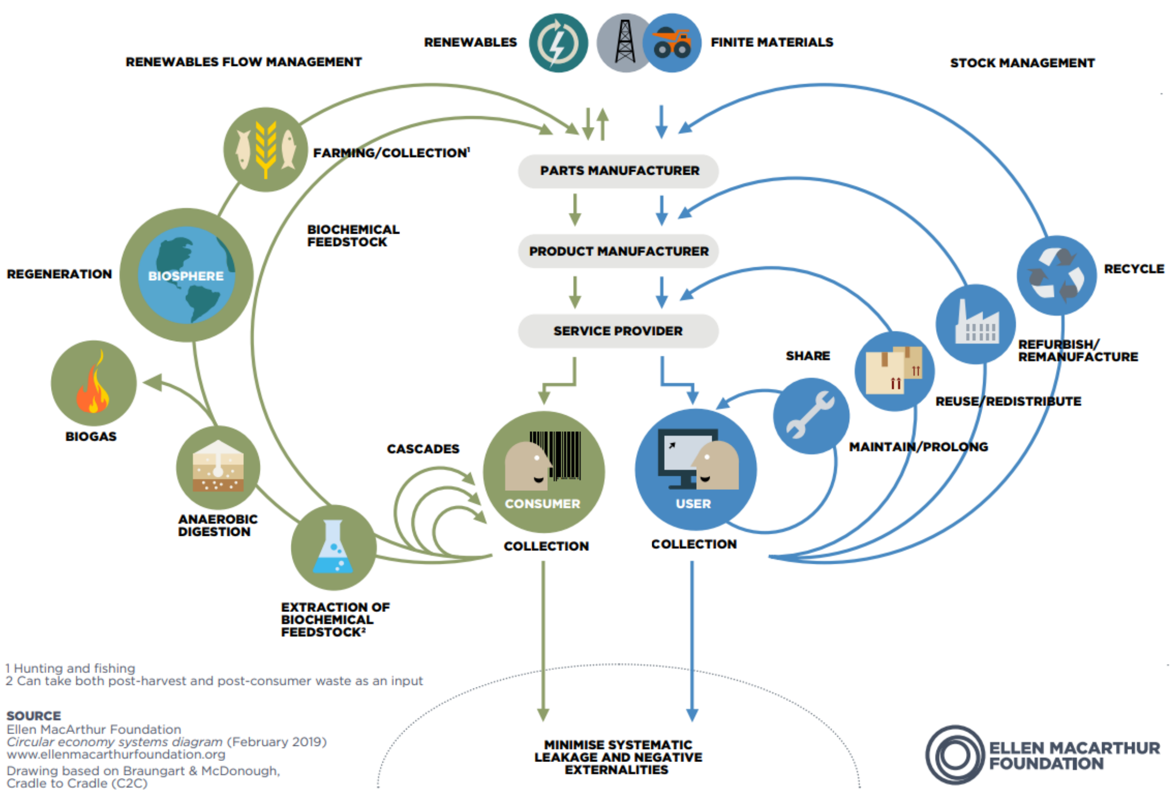

Figure 1 - Circular Economy Systems [2]
Abbildung 1 – Systeme der Circular Economy *[2]*

The current shift of the European Union towards a Circular Economy places the raw materials sector even more into focus than before. From the design of products for durability and reusability to the processing and recycling of resources, every stakeholder must be involved to make this transition successful. The current version of the EU's Circular Economy Action Plan highlights several key areas: electronics and ITC, battery and vehicles, packaging, plastics, textiles, construction and buildings, and food, water and nutrients. The raw materials industry, and especially mining and metallurgical industries, have an important role to play for these actions to be successful as they influence the full life cycle a material: from the design of products and alloys for reusability and recycling, going through flexible production processes allowing higher recirculation of materials, and finishing with high quality recycling of end-of-life products. [3]

For Germany especially, the potential economic benefits unlocked by the implementation of a Circular Economy are high. Raw Materials represent around 55% of the import's quantity of Germany, while semi- or finished product represent more than 70% of its exports, making the German economy highly dependent on resource imports. While this dependency could be limited by circularity measure, the Circular Material Use Rate of Germany, defined by the use of recycled material over the total use of material, still only amounted to 12,3% in 2019, slightly under the EU's average of 12,4%. Other western European countries achieved rates ranging from 20% to 28%, showing a stagnating implementation of circularity concepts in Germany. A Circular Economy scenario for Germany could lead to around 30% material saving by 2050 (Figure 2) and, although full cumulated benefits for the economy are difficult to calculate, could already represent around 30 billion Euro saving by 2030. [4] [5] [6]

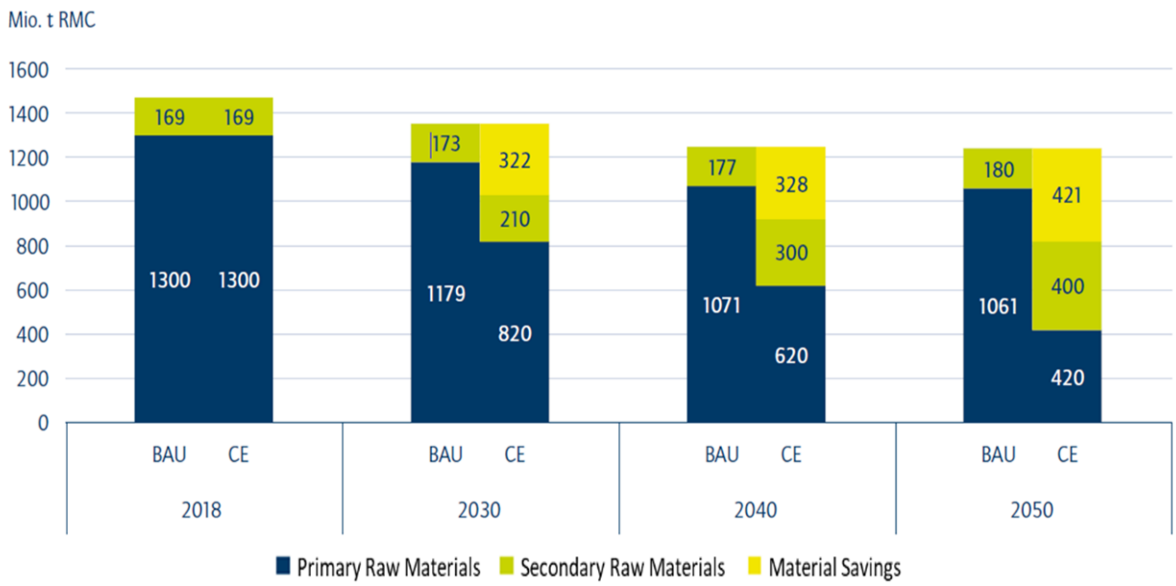

Figure 2 - Resource consumption of Germany in a Circular Economy scenario (CE) compared to a reference scenario (Business-as-Usual BAU), in millions of tons of Raw Material Consumption (RMC) [6]
Abbildung 2 - Ressourcenverbrauch Deutschlands in einem Circular Economy Szenario (CE) im Vergleich zu einem Referenzszenario (Business-as-Usual BAU), in Millionen Tonnen Rohstoffverbrauch (RMC) *[6]*

Alone in the year 2018, the use of recycled metals instead of primary resources lead to more than 1.5 billion Euro savings, and further decrease in primary raw material needs due to circular business models could lead to up to 10 times higher saving than direct cost reduction through recycling. This opportunity is of primary importance for the German raw material and manufacturing sectors. [6]

2. The case of E-Mobility: Circular E-Car

The automotive industry, especially considering the current rise of e-mobility, is at the core of many challenges towards a more circular economy. Unlocking the climate mitigation potential of e-car has to go hand in hand with circularity, improving on both the societal and material aspects. Firstly, the current conception of vehicle doesn't allow for high quality recycling, with only limited amount of metal recovered at the same quality as the input material, as shown in Figure 3. It is estimated that only around 8% of steel from cars can be recycled with a quality good enough to be used for new cars, even though most of the steel can be recycled. Secondly, cars are currently parked for more than 90% of daylight hours and typically not used at full passenger capacity. This leads to low material's utilization intensity, as more cars, and thus material, have to be mobilized to achieve a certain outcome: current estimations place the effective utilization of cars in Europe only at around 2%. [7] [8]

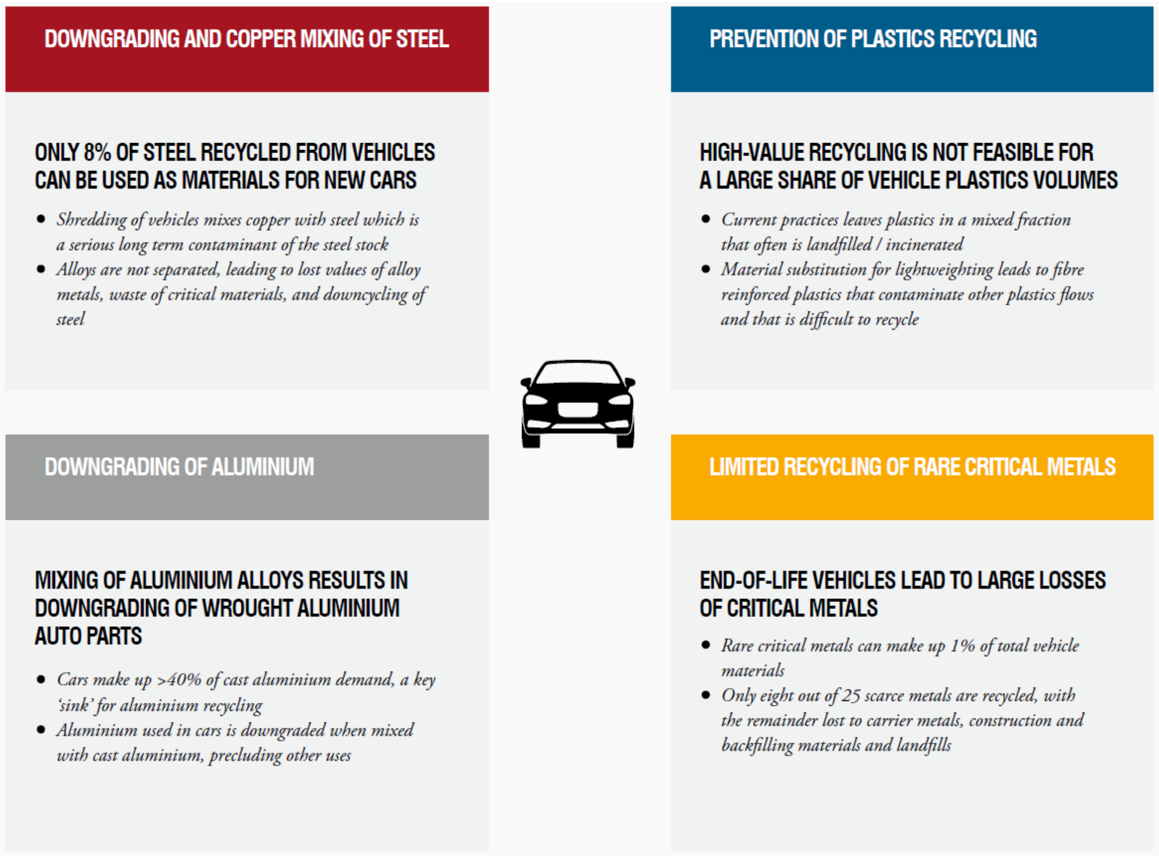

Figure 3 - Key challenges to circular material systems in the mobility sector [7]

Abbildung 3 - Zentrale Herausforderungen an zirkuläre Materialsysteme im Mobilitätssektor *[7]*

Similar problems arise for other material flows coming from an End-of-Life E-Car. Considering the fractions produced by dismantling and mechanical preparation, as shown in Figure 4, reaching high recycling rate for the whole car will necessitate a move towards more circularity. Copper contamination in steel, downgrading of aluminum alloys, loss of Critical Raw Materials in WEEE, incineration of textiles and other challenges can only be tackled through new design for circularity, taking into account potential reuse, remanufacturing, and finally recycling. [7] [6]

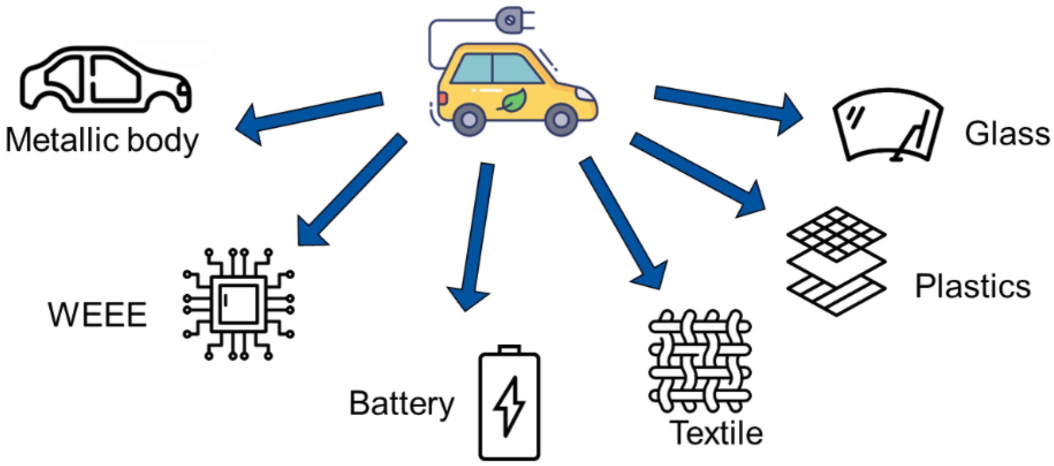

Figure 4 - Example of material fractions deriving from e-car dismantling (Own illustration)
Abbildung 4 - Beispiel für Materialfraktionen, die bei der Demontage von E-Autos anfallen (eigene Darstellung)

By combining material and societal innovations towards a circular e-mobility, CO_2 emissions from raw material use in passenger cars could be reduced by 70% by 2050. These innovations can be ordered into three categories: user, material, or business oriented. The first point concerns increasing the utilization of each car. New business models favoriting sharing of car within a customer group, or integration of private cars within a public transportation system, could decrease the stand-by time of vehicles and increase material utilization efficiency. These can be heavily supported by digitalization and automation processes, integrating e-mobility into the smart city concept. The second point concerns design for circularity, producing cars with higher lifetime and lower weight, optimizing the energy balance of the vehicles. With reuse, repair and remanufacture built in the design, the higher modularity of e-cars can also greatly improve their lifetime. The third point concerns the profitability of circular business models. By way of modularity and design for recycling, keeping End-Of-Life material flows more predictable in their composition and amount can reduce downgrading and thus producing higher quality product post-recycling. Such a value chain for e-mobility is schematized in Figure 5. [7] [6] [9] [10] [11]

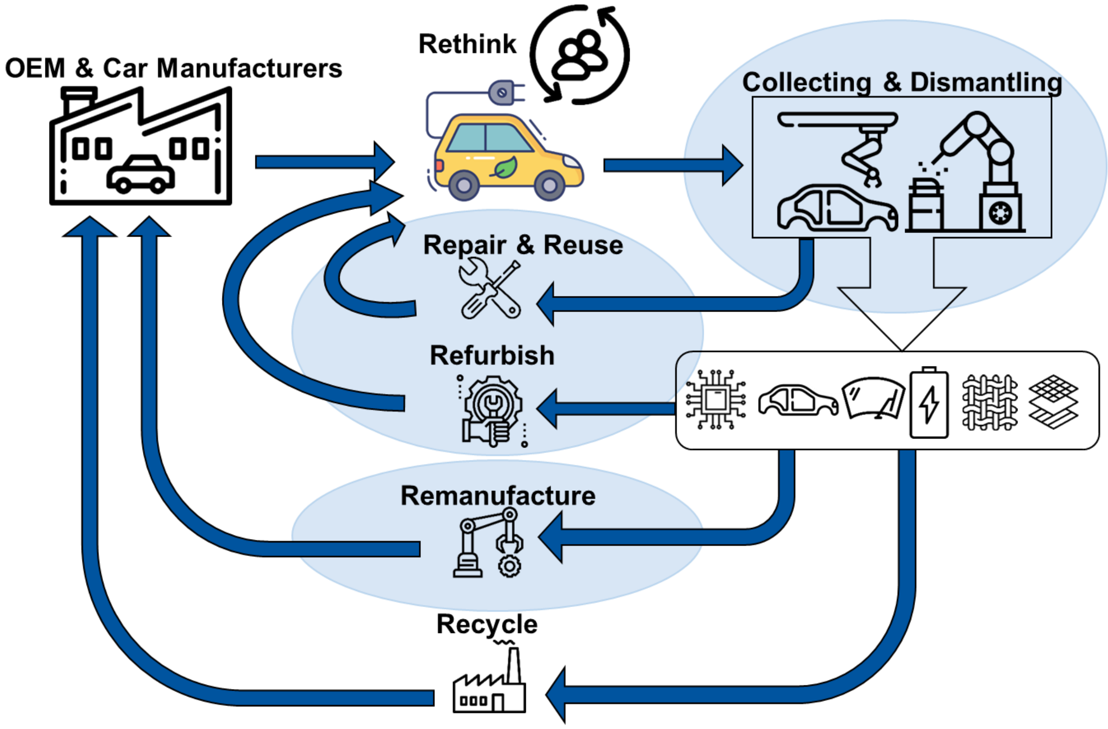

Figure 5 - Circular systems along the value-chain of the e-mobility sector (Own illustration)
Abbildung 5 - Kreislaufsysteme entlang der Wertschöpfungskette der E-Mobilitätsbranche (eigene Darstellung)

The case of e-mobility highlights one important necessity to work towards a Circular Economy: the need for multidisciplinary coordinated action. In a circular scenario, each part of the value chain has to communicate and adapt to the other parts, in order to maximize material utilization. To support this effort, Germany needs to create more multidisciplinary research and higher education infrastructures.

3. RWTH Aachen's Strategy: The Center for Circular Economy

Recognizing the importance of the Circular Economy in the future development of Europe's innovation, RWTH Aachen University has created the Center for Circular Economy. The Center pools the expertise of all RWTH Aachen faculties, to act as an enabler to the transformation of research, education and society towards a Circular Economy.

The activities of the Center are structured in three complementary thematic pillars: *Material Recirculation*, aiming at achieving high material value retention along the value chains to decrease primary production and emissions; *Product Sustainability*, focusing on the reduction of environmental and social impacts through design for circularity and longer product lifetime, while keeping high social and user acceptance; and *Circular Business Models*, aiming at more business sustainability by implementing a sharing economy and product-as-a-service models, as well as focusing on the creation of industrial symbiosis.

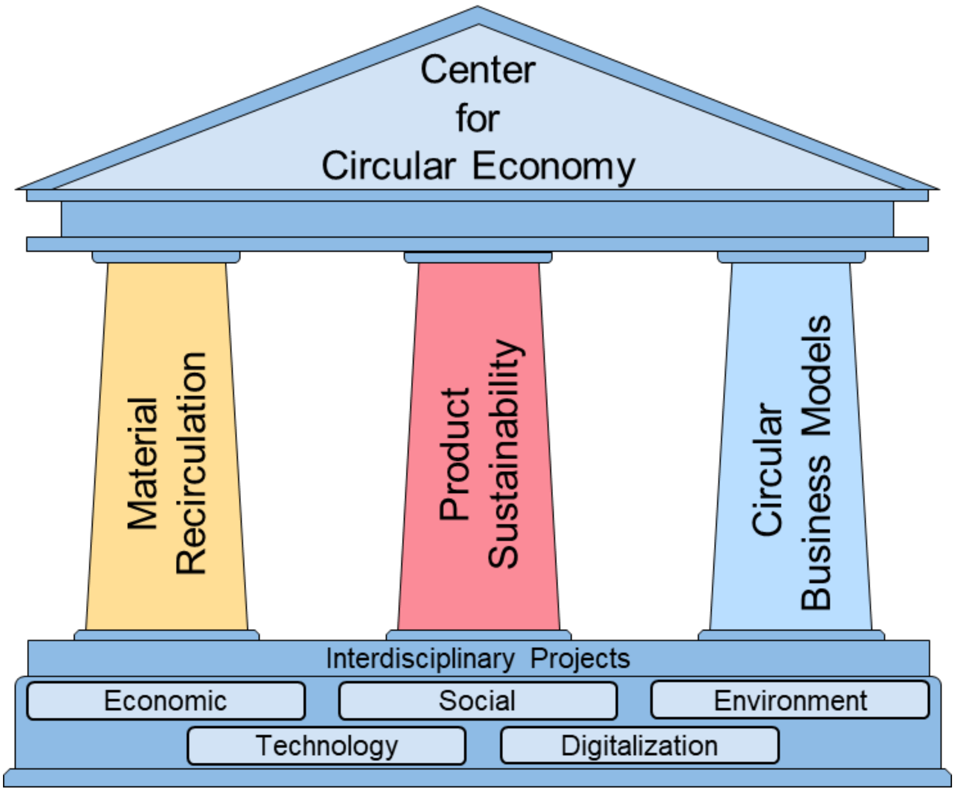

Figure 6 - The three thematic pillars of the Center for Circular Economy (Own illustration)
Abbildung 6 - Die drei thematischen Säulen des Center for Circular Economy (eigene Darstellung)

As a transdisciplinary platform linking research, industry, politics and society, the Center develops innovative solutions for the circular value chain of the future, having the highest possible value retention of materials while keeping high user acceptance.

4. Conclusion

The shift towards a Circular Economy represent a great opportunity for the raw material sector in Europe. Not only does a circular society contribute towards climate mitigation and a sustainable economy, circular business models can also lead to important material and economical savings. Current reports estimate potential saving of 32 billion Euros until 2030 in a circular economy scenario in Germany alone. Nevertheless, highly technological products are currently not adapted to the circular economy. Through better implementation of design for circularity, meaning design for several products loops like reuse and remanufacture, a higher material utilization intensity as well as quality recycling products can be achieved.

The e-mobility sector is a perfect example of the potential of circular design. Currently, utilization of cars is not optimized, with cars being used at roughly 2% efficiency considered time of use and passenger capacity. Adding to this the several challenges of material recycling, ranging from downgrading of steel and aluminum, to loss of critical raw materials and limited recovery of plastics, leaves place for improvement in the material balance of e-mobility. By adopting circular business models and a design for modularity, higher quality recycling as well as more intense material utilization could be ensured.

To tackle these challenges, Europe, and Germany, need to move towards a transdisciplinary approach to research and innovation. The Circular Economy can only be achieved by having all actors of the complete value chain, from raw material extraction to product generation, from user to recyclers, acting together and adapting their processes in a “waste-as-a-product” perspective. To this effect, RWTH Aachen University has created a Center for Circular Economy, offering a platform where research, industry, education, politics and society can act together to find tomorrow’s circular solutions to today’s material challenges leading to a sustainable transformation of our society.

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