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Future Challenges in Logistics and Supply Chain Management

MOVING IN CIRCLES: LOGISTICS AS KEY ENABLER FOR A CIRCULAR ECONOMY

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■ WHITEPAPER

MOVING IN CIRCLES: LOGISTICS AS KEY ENABLER FOR A CIRCULAR ECONOMY

The principle of the Circular Economy is to keep raw materials as long as possible within the economic cycle generally free from waste and emission. To do so, end-of-life products and materials must be kept at the highest possible level of value creation according to their original use. To realize such a circular way of economy adapted logistics concepts to coordinate both material and information flow are inevitable – beside approaches to product design for recycling and new business models. Developments of digitization, Industry 4.0 and Internet of Things offer solutions that have not yet been applied to a large extend. However, possible disadvantages of Circular Economy like rebound effects and increased demand for resources by deploying digital technologies must be taken into consideration. Due to its strong integration into the processes of production, use and waste management logistics in particular has to contribute to a sustainable economy. This whitepaper introduces logistical trends supporting the transformation towards a Circular Economy. The focus of the whitepaper is on the materials cycles of the technosphere consisting of non-renewable resources.

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WHITEPAPER

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The paradigm shift of the Circular Economy

In recent years, the concept of the Circular Economy caught more and more attention in research, industry and society. In the context of the strongly increased global economic development in recent years with decreasing raw materials and challenges of climate change and environment protection at the same time, the Circular Economy is to contribute to creating a sustainable, resource-efficient, low-carbon and competitive economy. Primary objective is, first of all, to guarantee the supply of raw materials by economizing resources and increasing resource efficiency. Closing cycles of products and materials supports decoupling the economic development from the consumption of resources. [1]

One of the biggest hurdles for that is organizing the cooperation of all stakeholders beyond different levels of value creation. It is necessary that the relations between producers and suppliers in (global) supply chain networks do not primarily focus on the manufacturing processes and the final product any more but are planned to successfully close the cycles. Here, logistics is decisive as it allows the linking of the different levels of value creation beyond the entire product life cycle. This includes – besides concepts for extending life cycles – integrated logistics concepts for both supply and disposal and an improved stock management. Moreover, reliable statements on availabilities of secondary parts and materials are as important as the control of product flow according to the principles of supply chain management. The developments of digitization, Industry 4.0 and Internet of Things offer new approaches for that, which have yet to be fully exploited.

The significant challenge consists in integrating stakeholders of the circular economy in the supply chains and the circulation of materials in production and economy systems so that the paradigm shift from supply chain management to managing "circular supply chains" can be accomplished. Possible negative effects like for example rebound effects or an increased consumption of resources by using digital technologies need to be considered. Due to its strong integration in the processes of production, use and waste management logistics is specifically responsible to not become part of the problem itself but make a contribution to a sustainable economy.

CONCEPT

Briefly, the term "Circular Economy" means turning away from the linear "take-make-dispose" principle (produce, use and dispose) towards an integrated, circular way of that always keeps the use and value of all products, parts and materials at the highest possible level. The model distinguishes between technical and biological cycles. Consumption happens only in biological cycles, where food and bio-based materials (such as cotton or wood) are designed to feed back into the system through processes like composting and anaerobic digestion. These cycles regenerate living systems, such as soil, which provide renewable resources for the economy. Technical cycles recover and restore products, components and materials through strategies like reuse, repair, remanufacture or (in the last resort) recycling. [2]

A study of Ellen MacArthur Foundation and McKinsey [3] demonstrates examples that about 95 percent of the value of used raw material gets lost in Europe whereas material recycling and energy recovery from waste captures only 5 percent of the original raw material value. An average product produced in Europe (except for buildings) only has a life cycle of nine years. For the purpose of a Circular Economy, very early on, products must be designed for recycling, hazardous materials must be avoided, manufacturing processes, use paths and business models taken in consideration and building up logistic systems towards life cycle management expedited.

The Circular Economy aims at the following activities: [4]

- ▷ **Reuse**: products, parts and components are reused after repair, upgrades or reprocessing while retaining the shape according to their original use.
- ▷ **Refurbishment**: products, parts and components are reused in secondary usage options while retaining their original shape.
- ▷ **Recycling**: extraction and further use of materials/substances from products.

Moreover, Circular Economy also includes models for maximizing the utilization and extending a product's life through collaborative approaches (e.g. "Sharing", "Collaborative Economy").

The Circular Economy is considered benchmark for new economic activities. Products are considered over their entire life cycle and beyond and all steps of the supply chain are included. That requires an extensive and strategic transformation of economy – for logistics that means moving away from classic supply chain management towards managing circular supply chains.

In addition to all positive effects, Circular Economy can also have disadvantages: e.g. rebound effects. Something is considered a rebound effect if increasing the efficiency of a technology leads to an extended use of this technology and therefore the originally achieved saving in resources is partially compensated or even overcompensated. Moreover, the implementation of digital technologies can lead to a higher consumption of resources as the production of semiconductor components is extremely resource intensive. [5] Necessarily, logistics processes will be oriented towards both the resources productivity and resources efficiency with respect to their impact in future so that logistics presents itself as part of the solution and not as part of the problem.

STAKEHOLDERS

Circular Economy is a project that will revolutionize economic activities. Such a change requires the synergy of numerous stakeholders, e.g. government stakeholders, companies and consumers.

Government stakeholders

Government stakeholders are important for Circular Economy as they can foster a sustainable economy through laws, investments, research programs and other incentives and avenge harmful behavior.

First and foremost, legislature regulates waste management and emissions of production processes through waste and environmental laws. The so-called waste hierarchy, recycling rates and regulations on the separation of specific waste streams are only some of the rulings. Moreover, legislature creates the basic conditions and incentives to induce companies to responsible and sustainable economizing (e.g. through extended producer responsibility, encouraging the use of secondary raw materials or biodegradable packaging, eco-design guidelines). In this context, the taxation of resources additionally to the taxation of labor is more and more discussed considering resource depletion and as to create a strong incentive for sustainable use of resources and respective climate protection effects. [6]

Legislature can also ensure to integrate the consumer into the Circular Economy more strongly. It must guarantee that consumers are given the necessary information for their purchase decisions (e.g. via obligatory eco-labels) and the recycling systems are designed in a way to integrate as many consumers as possible. The public sector itself also plays a role in the Circular Economy as local authorities for example take part in the economic cycle as intermediate, partner as well as purchaser themselves. Thus, it can strengthen the demand and with that also the market and standards for "circular" products under the motto of the so-called "green public procurement"

Companies

The **manufacturing companies** play a central role in the Circular Economy. With their decisions for the use of secondary raw materials, product design for recycling, new technologies and business models (e.g. "product as a service"), consequently taking over the producer responsibility and – in cooperation with retail – developing recycling systems and logistics concepts they make a decisive contribution to the success of the circular approaches.

One of the biggest hurdles is organizing the cooperation of all stakeholders beyond various levels of value creation. In the context of supply chain management there are already comprehensive, partly global relations between producers and suppliers in which the perspective of the production process respectively the end products is priorities within planning processes ("what do we need for a successful end product?"). However, in a Circular Economy the circulation of products and materials ("How can we guarantee that the product is recyclable as long as possible?") and the prerequisites for close cooperation of all partners, if necessary up to the final customers, need to be prioritized.

Besides producing industry and retail there are two more industries particularly affected by Circular Economy: the waste management business and the logistics sector.

The **Waste management and recycling industry** is facing the challenge to newly define its role in the Circular Economy and to integrate new technological standards into the own processes at the same time. It must get away from the push principle, which means offering the secondary raw materials processed from the left over waste without necessarily being able to reliably comply with the product qualities, delivery quantities and deadlines defined by customers. In future, it must orientate towards the pull principle usual in supply chains in which waste management companies and producers jointly define criteria for the production of premium, need-based secondary products and materials that find a ready market. Close cooperation is of significant importance for both sides.

In 2017, topics like digitization and supply chain management are still mostly new territory for the waste management sector. Digital technologies such as dynamic tour optimization or container identification have no far-reaching penetration in the sector currently. A study funded by the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety shows that Circular Economy can benefit the most from digitization but is at the same time significantly worse prepared than for the upcoming digital transformation compared to five more lead markets. [7]

Until now, the companies of the recycling industry are not or just partly involved in supply chains of producers and trade. In the course of implementing Circular Economy concepts, however, they must meet the respective requirements as supplier of secondary raw materials and be able to take part in the electronic exchange of necessary information. [8] In future, waste management enterprises specialized in logistics will moreover have to face enhanced competition with "classic" logistics service providers. While the processes of waste management mainly include both return and disposal processes, logistics for the Circular Economy must also consider logistical features of procurement, production and distribution in forward-looking supply chains of manufacturing industry while at the same time processing and carrying along the relevant information.

> In particular, the connection between waste management and recycling companies providing secondary materials on the one hand and the manufacturing industries as supplier on the other hand is one of the main logistical challenges of the transformation towards a Circular Economy.

The Circular Economy will help **classic logistics providers** to open up opportunities and broaden their portfolio. Because circulation of secondary materials leads to changing product streams which necessitate different logistics approaches. Examples are logistics for small spare parts, modular and repairable products or reverse logistics for end-of-life electronic devices. For example, courier, express and parcel services (CEP) already provide for the reverse logistics of distributed material flows today such as online rebuy systems for second hand clothes or second hand mobile phones (e.g. Momox-Fashion [9], "Handyankauf" of Deutsche Telekom [10]). Also collaborative business models for the shared use of products require more complex and dispersed transport logistics between the different users that could be partly organized by logistics service providers.

Consumers

Consumers will also have to contribute to a functioning Circular Economy with both their consumer behavior and their active participating in the collection systems, take-back schemes and reverse logistics concepts for end-of-life products. Although legislature, companies and industries can submit the necessary regulations, infrastructure and product offers designed to close materials cycles, the consumers ultimately decides which products they buy, whether they resell them or give them away and how they separate the waste streams.

In the last years, resource productivity within Europe increased considerably (by respectable 41% between 2000 and 2016 within EU-28 [11]) which shows that manufacturing industry seeks to exploit possibilities for an economical and efficient use of resources within production processes. Therefore, the main reason for the ongoing excessive use of natural resources seems to be consumer behavior, although a majority of European consumers (77%) would rather have products repaired than buy a new product according to a Eurobarometer study from 2014. [12] At this point, there is thus a gap between the consumers' wishes and the business models of the producers who give significantly higher priority to the sale of new products. This is also evident in the marketing strategies that generally do not aim at using products as long as possible in their campaigns but at selling new products. Although after-sales services are a key element of customer-relationship-management (CRM) and spare parts business leads to considerable revenues (e.g. automotive), these topics are hardly considered in marketing activities.

A variety of (mostly digital) tools providing information on sustainable consumption and solutions for recycling or proper waste management to the consumers may help to work against this trend. For example, apps provided by local waste management companies or "MyMüll.de" [13] inform about waste collection dates or help to allocate waste to containers. Apps for a sustainable lifestyle such as "Codecheck" [14] and "ToxFox" [15] provide information on harmful components and "Nabu Siegel-Check" [16] provide guidance for the various eco-labels.

DRIVERS AND BARRIERS

Although the principles of the Circular Economy are not new, they are subject to different barriers which delayed the complete transformation so far. However, recent developments and especially technological innovations accelerate the implementation to a previously unprecedented extent. Table 1 shows a selection of both barriers and drivers that have to be taken into consideration when developing models for a future Circular Economy.

Table 1: Selection of drivers and barriers for the transformation towards Circular Economy

Barriers	
Business Models	• Business models focus on selling (non-durable) goods • Transition to new (service-oriented) business models require radical change of mindset
Technologies	• Recycling technologies are technically immature • Data exchange beyond circular supply chains is not yet possible (data security/sovereignty)
Cooperation	• Lock-in effects (existing relations between supplier and customer) and complexity of established value chain networks • Major efforts to integrate the actors along all levels of the value chain
Products	• Products/materials are not designed for recycling (especially mass products with short innovation cycles such as smartphones) • Products and materials are too complex
Knowledge	• The producers' lack of knowledge of their products' materials composition (especially those of components and modules externally purchased) effectively prevents design for recycling
Costs	• Costs for logistics and recycling are high (compared to energy recovery from waste) • Costs for new systems deter the producers from investing
Markets	• Demand for secondary raw materials still too low • Primary material is still cheaper than secondary material • Sustainability plays no/subordinate role in procurement processes

Legal requirements	• Until now, there is no comprehensive legal basis for the Circular Economy; Regulation focusses on separate waste and environmental laws with only few connection to product/business laws
Consumer behavior	• Products serve as status symbols • Common »bargain hunter mentality«
Drivers	
Resource scarcity	• Volatile prices of primary resources • Import duties and market foreclosure
Legal Requirements	• Approaches for legislation on Circular Economy (e.g. eco-design, extended producer responsibility, »green public procurement«) • Restriction of waste incineration and landfilling
Technologies	• New production technologies, digitization, Industry 4.0, Internet of Things, disruptive technological innovations (e.g. internet platforms, apps, machine-to-machine communication, track & trace of containers) [17]
Sustainable development goals	• Compliance with the United Nations' »Sustainable Development Goals« to be seen as a task of the society as a whole and an individual responsibility of each company
Consumer behavior	• Growing environmental awareness • Increasing quality standards and service orientation (e.g. product-as-a-service, mobility-as-a-service)

Some drivers and barriers base on the same effect mechanisms – this demonstrates that stakeholders on different levels start rethinking their actions (e.g. a change in consumer behavior, adjustment of the legislation. However, there are still big efforts required to accelerate the implementation.

One of the biggest challenges remains the complexity of designing value creation networks in terms of a Circular Economy. Companies are often afraid of the costs and organizational effort with respect to the difficulties assessing opportunities and risks associated with a new business model (for example from selling new products towards service-based models). Especially small and medium sized companies struggle with this as they often fear the "cannibalization" of their core business model without having an equivalent replacement.

LEGISLATION AND POLICIES

So far, there has been no explicit initiative on Circular Economy in Germany that goes beyond the previous regulations of waste management. However, the German Resource Efficiency Program (ProgRess) of the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety lays down the guidelines for "making economic and production methods in Germany gradually more independent of primary raw materials, further developing and expanding the circular economy" and "securing the sustainable use of resources in the long term through social orientation towards qualitative growth". [19]

On a European level, the European Commission laid down the key elements of the Circular Economy in the "Action Plan for a Circular Economy" (so called "Circular Economy Package"). [20] The overall objective of Circular Economy is to "preserve the value of products, materials and resources within the economy for as long as possible and to produce as little waste as possible"" and thus to contribute to a sustainable, low-carbon, resource efficient and competitive economy. The action plan explicitly addresses a product's life cycle from production (product design and manufacturing processes), use phase up to waste management. A set of indicators is currently being discussed from the fields of production and consumption, waste management, secondary raw materials, competitiveness, innovation and economy being suitable to measure the progress of European economy towards a Circular Economy. [21]

The Circular Economy Package constitutes a first set of activities including the revision of some EU-regulations with view to the Circular Economy (e g. directive on waste (Directive 2008/98/EC), the packaging and packaging waste directive (Directive 94/62/EC), directive on batteries and accumulators and waste batteries and accumulators (Directive 2006/66/EC), directive on end-of-life vehicles (Directive 2000/53/EC) and the directive on waste electrical and electronic equipment (WEEE) (Directive 2012/19/EU)). The proposals include stricter recycling quotas especially for the packaging waste, a maximum landfill quota of 10% for all municipal waste valid from 2030 and suggestions for further individualization of extended producer responsibility.

Furthermore, it can be assumed that the so-called Ecodesign Directive (Directive 2009/25/EC) will also be affected in the course of further legal adjustments at EU level as it can also address requirements on eco-design beyond its current focus on energy consumption. European regulations regarding environment and consumer production such as the directive on the restriction of the use of certain hazardous substances in electrical and electronic equipment (RoHS-Directive 2011/65/EC) and the regulation concerning the Registration, Evaluation, Authorization and Restriction of Chemicals (REACH-Regulation (EC) 1907/2006) and accompanying rules and international agreements on the transshipment of waste within and beyond EU such as the Basel convention are currently not concerned. However, in the future they are likely to be also revised according to the objectives of the Circular Economy.

So called "right to repair" initiatives focusing on the repair of products are also part of the Circular Economy. In July 2017, in its "motion for a resolution on a longer lifetime for products" the European Parliament adopted further requirements regarding the easy access to repairs and spare parts and "discouraging the fixing-in of essential components such as batteries and LEDs into products". [22]

Representatives from European Commission and business and environment and consumer organizations currently discuss the measures proposed in the Circular Economy Package and the related legislation in a controversial way. However, this initiative is also considered as a strong signal of the European Institutions and their member states to seriously support the transition towards a Circular Economy.

> Experience in the environmental sector shows: Regulatory measures often trigger technological innovation (e.g. recycling technologies deriving from landfilling restrictions and recycling quotas). This applies also to the transformation towards the Circular Economy.

POSITIONING OF THE INDUSTRY

International waste management, recycling and industry associations characterize the Circular Economy as basis for sustainable growth. With a Circular Economy, Europe could be able to increase its grade of independence from other countries in terms of scarce resources. [23] In their position papers, they laid down framework conditions and requirements considered necessary for a successful transformation: [24, 25, 26, 27]

- Market creation for secondary raw materials and a fair competition between primary and secondary resources;
- Political instruments supporting the transformation such as reduced taxes on secondary raw materials respectively on products using such materials;
- Easy export and transshipment of recycling materials within Europe (to enable a Europe-wide waste planning);
- Increasing the manufacturing of products from secondary raw materials with a focus on repair and recycling (product design);
- Supporting the knowledge transfer from European Circular Economy companies to the rest of the world;
- A Europe-wide standard to calculate the recycling rates according to fixed parameters taking into account data from all steps of the circular value chain;
- A fair competition between public and private service providers.

The associations from all industries and sectors do not agree with the very detailed provisions on product design as they consider them as negative impact for the innovation capacity. [28] Furthermore, they ask to frame the provisions on the extended producer responsibility in a more flexible way. [29]

Orgalime – the European Engineering Industries Association representing the mechanical, electrical and electronic, metalworking and metal articles industries – is particularly affected by the Circular Economy activities. The sectors represented consist of multiple producers from the consumer and capital goods industry with a turnover of ca. 2,000 billion Euro in 2016 and standing for more than a quarter of the European production. [30]

In its position papers on the Circular Economy Package and Circular Economy Monitoring Framework, Orgalime is generally positive about the objectives of optimizing resource use and "green growth". It identifies specific points such as waste management (landfill ban for recycling materials, prohibition of illegal exports of electrical and electronic waste, extended producer responsibility for all stakeholders within the waste management sector), quality standards for secondary raw materials, consistency in European waste and chemicals laws and mandatory use of "Life Cycle Costing" in public procurement. [31] However, Orgalime warns against a too narrow and isolated focus on the use of secondary raw materials and particularly rejects a mandatory use of secondary materials by the manufacturers. [32]

Logistics in the Circular Economy

Logistics in the Circular Economy has to follow a different approach than logistics in the waste management and recycling industries does today, making advances in terms of processes and technologies used to fulfill its tasks. In the Circular Economy, logistics has to fulfil more than classic take-back and disposal logistics of today's waste management services. Information and communication technologies will allow the integration of all actors along the value chain and enable new business models.

Up until now, logistical value creation networks have been characterized by a linear flow of materials, culminating in the disposal of goods associated with considerable material and resource losses. This practice creates high amounts of materials' and value losses across an entire an economic system. Within this system, logistics is divided into two parts:

The "classic" logistics functions support procurement, production logistics and distribution of new parts and products whereas waste disposal logistics focusses on processes at a product's end of life. The utilization phase between the production of consumer and industrial products and the processes of waste management constitutes a kind of intermediate stage that causes change of ownership and disrupted information flows within the products life. End-of-life products together with their inherent information, components and raw materials are less effectively recycled as it would be possible within in an effective Circular Economy. In addition, supply chains mainly focus on the production and distribution of non-durable goods and only rarely aim at closing loops in order to repair products. However, one of the most significant challenges in the transformation towards the Circular Economy is the integration of the recyclers as suppliers of high quality secondary products, components and raw materials on the one hand and the manufacturers buying these materials and offering repair services on the other hand. [33] In this respect, logistics is one, if not the most important factor of success.

If used systematically and enhanced respectively, current logistics trends and developments in all fields of production and distribution of products can help supporting the transformation towards a Circular Economy. Vice versa, the potential of the Circular Economy will only be realized when adequate logistics solutions are used.

TRENDS AND DEVELOPMENTS

Atomization of Shipments

The ongoing expansion of e-commerce increasingly leads to the atomization of transport units and thus, to extensive transport interdependencies between manufacturers, traders and end users. In turn, this leads to potentials within the current collection of small and micro amounts of valuable materials in the framework of take-back systems respectively the classic redistribution logistics. For example, trucks of CEP services usually start their tours fully loaded whereas they will come back (partly or fully) empty. This free capacity piling up during daily tours could now be used for the redistribution of smaller goods. One example for such a use case within the Circular Economy is the take-back of used toner cartridges and redistribution to the manufacturers (e.g. Brother, Samsung) organized by courier services.[34, 35] Also, in some cases the consumer can send back their used electric or electronic equipment to the manufacturer, retailer or other third parties via such a system.

Information Logistics and Data Sovereignty

Current efforts to enhance intelligent and targeted use of data in industrial production focus on the provision of customer and actor specific data to be used in logistics and production processes while respecting the highest standards for data security and data sovereignty at the same time. [36] In this context, the "Industrial Data Space" initiative (IDS), co-founded by Fraunhofer IML, aims at creating secure data spaces to realise a broad cooperation between enterprises from the manufacturing industry and the logistics sector. For the time being, the initiative focusses on the forward logistics in supply chain networks towards the end users. Nevertheless, the principles of the IDS can also be applied to post-consumer value chains in the Circular Economy where they help providing information on material contents in products even beyond the products' end of life. This can bring a valuable contribution to closing materials cycles. By facilitating the secure exchange and linkage of data in trusted business ecosystems the reference architecture of the Industrial Data Space can help to provide information relevant for treatment and recycling of end-of-life products while at the same time ensuring the security of the manufacturer's data.

One of the most important challenges with regards to digitization of logistics processes are technologies for securing transactions between different actors within value chains. One example is the Blockchain technology with its main areas of application, e.g. crypto currencies and smart contracts in the financial industry and insurance sector. The application of this technology within the logistics sector is possible, yet still at the beginning. [37]

New manufacturing technologies

New manufacturing technologies such as additive manufacturing enable other, decentralized methods of production which again lead to the deflection of the manufacturing processes and the materials' supply and waste disposal towards the end user. At the same time, new technologies and methods of production allow for an increased use of recycled material in excess of today's amounts. Fraunhofer IML is currently pursuing this approach together with other Fraunhofer institutes in the joint "BauCycle" project for the production of high-quality products from secondary mineral raw materials from construction and demolition waste. In this context, the implementation of innovative approaches to industrial production can only be realized on the basis of innovative logistics solutions. [38] Efforts to use secondary raw materials or re-use production waste for new metal and plastics based products in additive manufacturing processes are already being made. [39]

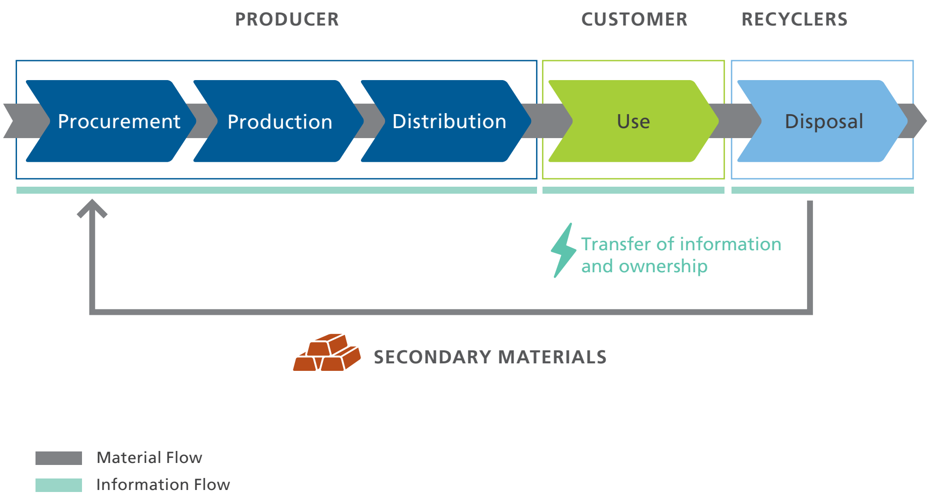

Figure 1: Linear material flows in today's »classic« supply chains

Furthermore, manufacturing on demand (MOD) and the increasing trend towards customer-oriented "Lot-size-1 Production" of highly individualized products necessitate innovative supply chain designs [40] which significantly differ from previous approaches and the structures of which can easily be interlinked with redistribution processes.

Autonomous Systems in the Industry 4.0

The term "Industry 4.0" describes the transformation of the manufacturing industry towards automation and a data driven 4th industrial revolution in which cyber physical systems (CPS) enable self-organizing processes in an unprecedented way. In cyber physical systems informational (cyber) components and mechanical or electronic and sensory (physical) components are merged to form an intelligent system. [41] Within CPS, different intelligent objects connect to each other, autonomously optimize the networks themselves and – in co-operation with human interactors – solve problems. [42]

Dynamic, self-organizing supply chain networks support efficient manufacturing processes at the highest possible capacity of production and transport. Applied within the Circular Economy, the enhanced supply chain transparency of the Industry 4.0 together with the integration of recyclers in the networks on equal terms can help manufacturers extending their materials base towards secondary raw materials.

Social Networked Industry

A new dimension of Industry 4.0 is the so called "Social Networked Industry" which presents the concept of a socio-technical system where people and machines work together as a team within industrial ecosystems. In terms of the factory of the future, this means that people and machines could communicate with each other in (digital) social networks which will lead to more efficient processes and put people more in the center of production. [43]

Daily business in the waste management sector is characterized by high physical load of the workers, which could be reduced by the use of technical equipment. The approaches of the Social Networked Industry in the future can support the development of adequate interfaces to assist this man-machine interaction.

LOGISTICS TRANSFORMATION

The trends and technologies outlined in this chapter can contribute to the long-term objective of the Circular Economy at different stages of the value chain. They can enhance logistics within linear value chains with low priority to circulating resources such as shown in figure 1. In such value chains, they can close the information gaps between production, use phase and downstream waste management processes as well as between the systems of manufacturers, recycling industry and third parties that are currently not sufficiently aligned to each other. Figure 2, in contrast, illustrates such a gap closure within a value chain.

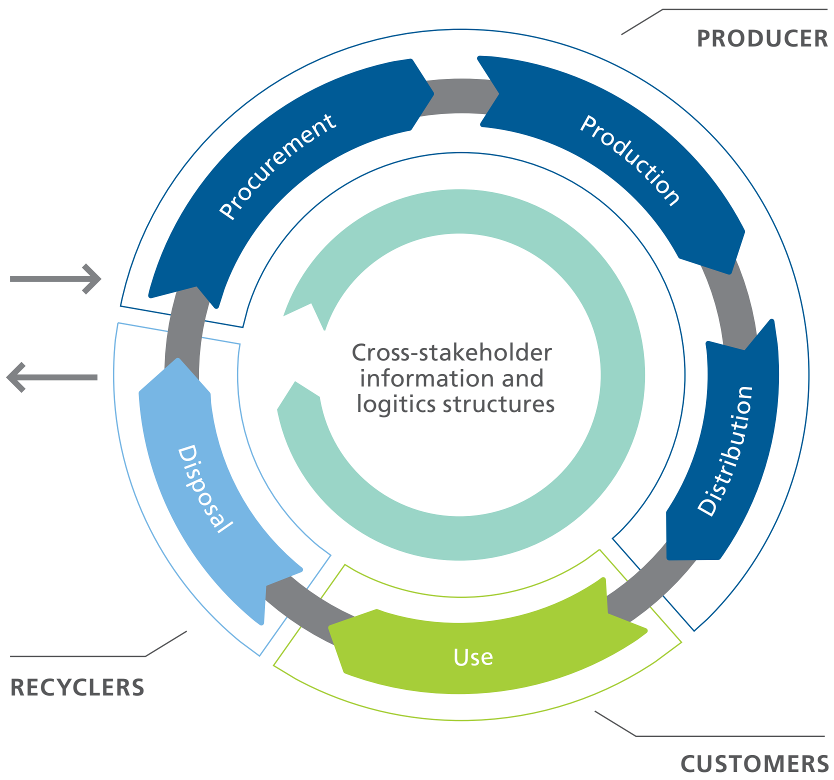

Figure 2: Value creation within the Circular Economy

The Circular Economy is characterized by changing but still largely continuous mass flows and material streams across the value added levels. This results in extensive logistics tasks and challenges, which, however, can be addressed by logistical and technological approaches available on the market.

The increased transparency along the circular value chain serves as the basis to ensure a considerable circulation of post-consumer products, e.g. reconditioned electronic devices, components, or secondary raw material.

Principally, the trends and developments described can be applied in different use cases of the Circular Economy (see table 2).

Table 2: Logistics trends and use cases for the Circular Economy

Technology/Trend	Use cases (examples)
Atomization of shipments	• Reverse logistics of valuable material such as in end-of-life electric and electronical equipment Reverse logistics of hazardous waste
Information logistics and data sovereignty	• Use of decentralized systems for the provision of information (even on highly individualized products) relevant for the processes in the circular value chain »material passport«) • Protection of transport documentation and respective data security
New manufacturing technologies	• Use of secondary raw material as a substitute to primary raw material • Integration of secondary raw material producers as raw material supplier in the supply chains
Autonomous systems in Industry 4.0	• Autonomous supply chains make use of raw materials and components from primary and secondary sources on equal terms • Transport planning within supply chain networks is done across actors and functions for an optimal use of transport capacities
Social Networked Industry	• Better human-machine-interaction to improve the work efficiency such as to avoid redundant paths in waste collection • Augmented reality-assisted disassembly of complex products helps raising recovery rates and reducing the risk of injury

In Circular Economy, the positive effects of trends and developments appear on different logistical levels – from the strategic network level within a supply chain down to the operational level of daily business. The trends and use cases described affect the actors involved and the environment in a broader way as shown in table 3.

Table 3: Impacts of logisticsl trends on environment and stakeholders

	Autonomous systems	Atomization of shipments	Social Networked Industry	New Production Technologies	Digitization and Data Sovereignty
Producer	↑	↑	↑	→	↑
Customer	?	↑	?	↑	→
Recycling business	↑	→	↑	→	↑
Enviroment	↑	?	?	?	↑

Implications of logistical trends for actors and the environment

↑ positive effects
→ no change
? unclear outlook, further research required

Although positive impacts on actors and environment can be identified, the effects cannot be estimated for all levels of a Circular Economy. In this regard, it is important to know how the transformation will finally proceed and to what extend further effects like for example rebound effects will occur. Consequently, there is more demand for research.

Scenarios for a Circular Economy

Current efforts towards a Circular Economy are mostly politically driven and still early stage. No certain forecast is possible as to how legislative conditions will change over the coming years and how markets will react to it. For this reason, in the following chapter the authors propose two scenarios. They describe the implications of legislative circumstances on market participants and logistics. The first scenario imagines a more conservative follow-up of current efforts and therefore proposes an only less ambitious transition towards a Circular Economy. The second scenario describes a much more politically driven transformation than in the first scenario. In analogy to the German turnaround in energy policy following the Fukushima accident in 2011, the scenario anticipates a legislative framework that is more ambitious in driving enterprises towards a Circular Economy. Additionally, both scenarios demonstrate how the logistics trends and technologies described in the previous chapter will help to realize closing the gap to a Circular Economy.

GRADUALLY CLOSING THE LOOP

In this scenario, legislature on a European level mostly develop the legislation and its instruments (producer responsibility, waste and environmental laws, etc.) in an evolutionary way. These efforts are accompanied by collecting more Circular Economy focused indicators for various sectors (e.g. production, consumption, waste management, secondary raw materials, competitiveness, innovation and economy), which allow assessing the EU member states' transition towards a Circular Economy. This legislative environment still allows for linear value creation. In this scenario, innovations of technology and business models are mostly price-driven. The following table illustrates the framework parameters.

Category	Characteristics
Producer responsibility	• The Circular Economy principle will be applied to additional industries; individual approaches of enterprises will not be addressed.
Recycling rates	• Continuation of today's recycling rates mandatory in EU member states that are based on mass flows and will be increased over time (steering function).
Indicators	• Indicators according to the EU Circular Economy monitoring framework are collected in all EU member states for informational reasons and without steering function.
Standards	• Quality standards for secondary raw materials do exist only for a small number of materials.
Products	• Durability and reparability of products are addressed by moderate increase of regulations regarding defects liability.

Table 4: Regulatory framework conditions for the »gradually closing the loop« scenario

For companies in the manufacturing industries, this scenario implies only a slight increase in mandatory regulations accompanied by very few incentives to individually pursuing producer responsibility schemes, which is why participation in collective take-back schemes will still be common. This leaves limited possibilities for companies to actively influence mass streams and material qualities. The systems remain mostly an expense factor for companies although they might benefit from revenues from selling secondary materials. This leads to a focus on recovering only high volume materials that can easily be processed without considering the overall environmental implications. Due to the lack of common standards for secondary materials, companies are reluctant to make use of these materials on a large scale. Direct communication between recycling companies and producers is minimal; trading secondary materials is commonly facilitated via anonymous platforms. Service based business models are restricted to few companies in selected industries (e.g. investment goods) aiming to increase the overall product life span.

The **recycling companies** will face increasing mass flows of end-of-life materials that can easily be processed. However, because the profitability of new recycling technologies will still be based on world market prices, the commercialization of secondary materials will still be difficult.

Market perspectives for **waste disposal logistics companies** are good in this scenario because of little structural changes and increasing end-of-life material flows. Due to a lack in terms of incentives for companies to move to new business models, perspectives for individual logistics solutions and services supporting these business models (e.g. by reintegrating forward facing supply chains and reverse logistics streams) is limited.

Overall, **logistics companies** develop their applications and services slowly towards the support of closed loops. Their focus remains, however, on establishing bilateral connections between supply chain processes by providing interfaces for communication between these partners. New developments such as specialized containers may for instance allow dual use for distribution and disposal purposes and can be applied across company networks. Utilizing courier, express and parcel service networks for circulating selected materials and goods will increase in areas where market prices for these will justify the logistics costs and efforts behind it.

Overarching coordination and steering across companies within a **supply chain network** is unlikely in this scenario. This lack results from limited standards for secondary raw materials and high availability of cheaper primary materials. This leads to no centralized availability of information across supply chains and relevant data and information for the holistic optimization is unavailable to all. The result is an inefficient treatment of end of life products.

Overall mass flows for material recycling increase, but the incorporation of ecological criteria when considering the right treatment remains suboptimal. Generally spoken, no noteworthy effect on overall resource consumption is to be expected from this scenario.

Logistics supports closing loops, but fails to do so to the full extent despite the technological innovations. This is due to the lack of market actors that are willing to entirely embracing Circular Economy principles.

FULL CIRCULAR TRANSFORMATION

In this scenario, the European legislation aims at a consequent and global transformation towards a Circular Economy. Resource consumption is sanctioned (e.g. by resource taxes) and additional regulative policies are installed (e.g. consumption taxes) to prevent rebound effects. A set of appropriate circularity indicators to quantitatively and qualitatively assessing resource consumption and resulting environmental impacts are applied across Europe. Within EU member states mandatory aims are set and sanctions are imposed for countries and actors not achieving the aims. Market actors will react adaptive at first, but quickly embrace the new regulations and develop innovations according to the changed marked environment.

Table 5: Regulatory framework conditions for the scenario »full circular transition«

Category	Characteristics
Producer responsibility	• The principle is applied widely and producers are obligated to participate in a system or provide equivalent alternatives • Previously external costs are internalized (e.g. via environmental taxes)
Recycling rates	• Resource consumption is subject to sanctions (e.g. by resource taxes), regulatory measures aim to supress the rebound effect.
Indicators	• Indicators to quantitatively and qualitatively assessing resource utilisation and environmental impacts are used across Europe and mandatory goals are set on the level of the EU member states.
Standards	• Standards exactly define the characteristics of secondary raw materials..
Products	• Durability and reparability are regulatory set aims and as such highly prioritized in product design, marketing and customer loyalty strategies of manufacturers. • Spare parts and repair manuals are available for all market participants. • Data regarding the resource consumption of products is available on a product level and can be used by all market participants across the whole product life cycle.

The scenario illustrates a substantial shift of the principles of industrial production towards an increase of the importance of repairing and maintenance at the cost of selling new products. As a result, the overall smaller amount of waste is recycled to higher quality secondary raw materials. Export volumes of finished goods decrease as well as the import volumes of raw materials and semi-finished products Table 5 summarizes the regulative framework conditions for this scenario.

The increase in mandatory obligations poses a significant challenge for manufacturing companies and their business models. Decreasing sales volumes for new products (in some cases compensated through the selling high-value products) leads to shifts within the market. Rising demands for repair work and spare parts (driven by manufacturers, retail and third parties) requires new approaches through existing or new market participants. Requirements for long time spare part supply change drastically (e. g. in terms of backward compatibility of components and parts).

Manufacturing companies cooperate more closely with increasingly specialized disassembly and recycling industries or integrate these parts of the value chain. Augmented reality (AR) and virtual reality (VR) applications support repair and disassembly processes. Incorporating secondary raw materials into their products becomes more attractive for manufacturers while high data transparency becomes consensus.

The **recycling industry** will face a market shakeout. In total, quantities of waste generated and circulated will decrease while the quality of the materials within the stream increases. Recycling companies tend to specialize and integrate more closely with the supply chains of manufacturing industries. They extend their business to new areas in order to better compete with manufacturers (e.g. in the field of refurbishing used parts). **Waste disposal logistics** moves towards managing and disposing of residual and hazardous waste which will not be used further.

The **logistics industry** will change as well. "Traditional" applications in parcel and bulk goods logistics decrease in market share (especially in the fields of waste disposal logistics and resource distribution logistics). Specialized solutions for small quantities (e. g. used products and spare parts) have good market perspectives. The overall resource consumption of logistics systems and businesses has to be reduced considerably.

Supply chain networks provide a decentralized, comprehensive information infrastructure allowing companies interacting with one another to align their decisions with overarching goals of circular supply chains as well as to their own strategy and societal demands. No centralized management of supply chains is needed.

Standardized and quality controlled secondary raw materials can be obtained from various sources and are integrated with the procurement strategies of supply chains. The data infrastructure helps to comprehend origin and quality of materials through the supply chains in an accessible manner. Principles of the Industry 4.0 are applied on company scale and support autonomous planning of logistics tasks by aligning underlying systems with the requirements of new and efficient spare part strategies and on demand-production of components. Companies within the Circular Economy rely more strongly on AR and VR technologies to support workers during the disassembly of products and part harvesting from devices. Products are identifiable by smart labels and autonomously find their routes within logistics networks.

Logistics creates closed loops for products, materials and information in which actors across all levels of value creation networks can cooperate. However, Logistics itself has to decrease its environmental impact and resource consumption.

CONCLUSION

The scenarios laid out in this chapter describe contrasting ideas of a Circular Economy. Based on existing structures, interdependencies within global value and supply chains and differing national interests of EU member states, no actual prognosis can be made how and how quickly the development of a Circular Economy will take place. On the one hand, a continuation of the existing path beyond the status quo is likely. On the other hand, a disruptive transformation towards a Circular Economy is unlikely to happen over-night. A variety of transitional scenarios can be anticipated, in which existing approaches will be refined and new ideas will come to fruition.

Both scenarios demonstrate, how technological developments in logistics can be applied in order to support the transition towards a Circular Economy on different levels and in different speeds. In many cases even the more conservative first scenario shows positive effects of logistics trends and technologies on some actors and the environment, while in other cases, these effects cannot be assessed sufficiently. Only continuously developing these innovations further will help making them applicable to the full transition towards a Circular Economy.

Outlook

The Circular Economy is a project requiring a tremendous effort and aims at entirely transforming the way businesses currently operate. Logistics is crucial to this transformation because of its relevance for all levels of the Circular Economy: From physical transport of goods to transferring information to self-organizing supply chain networks to developing and supporting new business models. Logistics connects actors across the entire value chain and incorporates regulatory bodies and customers alike. Resulting challenges can be tackled by already existing logistical-technological approaches. However, we do see additional demand for research and development activities in the following fields:

- **Supply chains in the Circular Economy**
  Coming from the question "how can actors within the Circular Economy cooperate efficiently?" a structured analysis of standards for materials, transportation, communication and contract-based interaction of partners along the supply chain is necessary. Recycling companies will become suppliers of high quality secondary raw materials and thus contribute to closing the gap to a Circular Economy.

- **Industrial production in the Circular Economy**
  Focus of this research area are technologies and manufacturing principles enabling future, Circular Economy-ready products. Based on the question "in which way does industrial production in the Circular Economy have to change?" research must be undertaken to develop approaches to a less resource consuming production within manufacturing plants and supply chain networks of the future.

Additionally, regulatory measures are decisive factors for the achievement of goals related to the Circular Economy and for supporting further innovation. However, today it is still unclear in which direction and at which speed the regulatory framework for the transformation will change.

> Logistics alone cannot accomplish the transformation towards a Circular Economy in the same way that the transformative potential cannot be tapped without apt logistics solutions. Application-oriented innovations to actually realize circular logistics networks have to be developed under consideration of rebound effects and environmental impacts.

Literature

[1] Scheelhaase, T.; Zinke, G. (2016): Bericht: Potenzialanalyse einer zirkulären Wertschöpfung im Land Nordrhein-Westfalen. Studie im Auftrag des Ministeriums für Wirtschaft, Energie, Industrie, Mittelstand und Handwerk NRW MWEIMH. Düsseldorf-Hamburg-Berlin.

[2] Ellen MacArthur Foundation (2017): Circular Economy Overview. The concept of a circular economy. URL: https://www.ellenmacarthurfoundation.org/ – Accessed October 1, 2017.

[3] Ellen MacArthur Foundation, McKinsey Center for Business and Environment (2015): Growth Within: A Circular Economy Vision for a Competitive Europe.

[4] Verein Deutscher Ingenieure (Hrsg.) (2002): VDI-Richtlinie 2243: Recyclingorientierte Produktentwicklung. Beuth Verlag GmbH. Berlin.

[5] Boyd, S. B. (2009): Life-cycle Assessment of Semiconductors; Dissertation; University of California. Berkeley.

[6] Bahn-Walkowiak, B.; Bleischwitz, R.; Kristof, K.; Türk, V. (2007): Instrumentenbündel zur Erhöhung der Ressourcenproduktivität. Wuppertal Institut für Klima, Umwelt, Energie (Hrsg.). Wuppertal.

[7] Büchele, R.; Andrä, P. (2016): Die Digitalisierung in der GreenTech-Branche. Handlungsbedarfe für Unternehmen der Umwelttechnik und Ressourceneffizienz in Deutschland. Roland Berger GmbH (Hrsg.). München.

[8] Fennemann V. (2013): TraCy. Tray Cycling – Logistics for Urban Mining. In: Clausen U., ten Hompel M., Klumpp M. (Ed.): Efficiency and Logistics. Lecture Notes in Logistics. Springer, Berlin, Heidelberg.

[9] Momox-Fashion (2017). URL: https://www.momox-fashion.de – Accessed October 13, 2017.

[10] Deutsche Telekom (2017): https://shop.telekom.de/handyankauf – Accessed October 10, 2017.

[11] Eurostat (2017): Resource productivity statistics. URL: http://ec.europa.eu/eurostat/statistics-explained/index.php/Resource_productivity_statistics – Accessed October 10, 2017

[12] European Commission (2014): Flash Eurobarometer 388: Attitudes of Europeans towards Waste Management and Resource Efficiency. Brüssel.

[13] Junker Mobile Mind (2017): MyMüll.de. URL: https://www.mymuell.de/ – Accessed October 13, 2017.

[14] Codecheck AG (2017): Produkte checken und gesund einkaufen. URL: https://www.codecheck.info/so-gehts/start – Accessed October 13, 2017.

[15] Bund für Umwelt und Naturschutz Deutschland e.V. (BUND) (2017): ToxFox: Scannen, fragen, giftfrei einkaufen. URL: https://www.bund.net/chemie/toxfox/ – Accessed October 15, 2017.

[16] NABU (2017): NABU Siegel-Check. URL: http://siegelcheck.nabu.de/ – Accessed October 15, 2017.

[17] Lacy, P.; Keeble, J.; McNamara. R.; et al. (2014): Circular Advantage. Innovative Business Models and Technologies to Create Value in a World without Limits to Growth. Accenture.

[18] Sustainable Development Knowledge Platform (2017). URL: https://sustainabledevelopment.un.org/ – Accessed October 12, 2017.

[29] Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit (2015): Deutsches Ressourceneffizienzprogramm. Programm zur nachhaltigen Nutzung und zum Schutz der natürlichen Ressourcen. 2. Aufl. Berlin.

[20] European Commission (2015): Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Closing the loop - An EU action plan for the Circular Economy. Brüssel.

[21] European Commission (2017): Monitoring framework for the circular economy. Brüssel. Joint meeting of the working groups Environmental accounts and Monetary environmental statistics and accounts, 4.5.2017. URL: https://circabc.europa.eu/sd/a/6e2a8ec7-cae2-4ae4-a2f8-073b305b7a33/ENV_ACC-MESA_WG_2017_04.1%20Monitoring%20framework%20circular%20economy.pdf – Accessed October 13, 2017.

[22] European Parliament (2017): European Parliament resolution of 4 July 2017 on a longer lifetime for products: benefits for consumers and companies. Brüssel.

[23] Municipal Waste Europe et al. (2015): Open letter regarding the withdrawal and renewed discussion of the circular economy package to President Jean-Claude Juncker, European Commission.

[24] EuRIC - The European Recycling Industries’ Confederation (o.J.): EuRIC concrete proposals for a market-driven circular economy. URL: https://www.euric-aisbl.eu/position-papers/item/84-euric-concrete-proposals-for-a-market-driven-circular-economy – Accessed October 13, 2017.

[25] FEAD - European Federation of Waste Management and Environmental Services (2014): Driving the Circular Economy – A FEAD Strategy for 2014-2020. Brüssel.

[26] VKU - Verband kommunaler Unternehmen e. V. (2015): VKU begrüßt den ganzheitlichen Ansatz zur Weiterentwicklung des Circular-Economy-Paketes. Berlin. URL: https://www.vku.de/presse/pressemitteilungen-liste/liste-pressemitteilungen/archiv-2015-pressemitteilungen/pressemitteilung-4615.html – Accessed October 14, 2017.

[27] BDE - Bundesverband der Deutschen Entsorgungs-, Wasser-, und Rohstoffwirtschaft e.V.; ITAD - Interessengemeinschaft der thermischen Abfallbehandlungsanlagen in Deutschland e.V.; VDMA - Verband Deutscher Maschinen- und Anlagenbau e.V. (Ed.) (2016): Branchenbild der Kreislaufwirtschaft. Berlin.

[28] VDMA - Verband Deutscher Maschinen- und Anlagenbau e.V. (2015) Kreislaufwirtschaft: VDMA warnt vor zu viel Detailregelung. Frankfurt. URL: https://www.vdma.org/article/-/articleview/8955537 – Accessed October 12, 2017.

[29] Municipal Waste Europe (2013): Extended Producer Responsibility. Brüssel. URL: https://www.municipalwasteeurope.eu/sites/default/files/Positions/8.%20MUNICIPAL-WASTE-EUROPEonEPR.pdf – Accessed October 12, 2017.

[30] Orgalime: European Engineering Industry Association – About us. Brüssel. URL: http://www.orgalime.org/page/about-us – Accessed October 12, 2017.

[31] Orgalime (2016): Position Paper Action Plan Circular Economy: Closing the Loop; Brüssel.

[32] Orgalime (2017): Orgalime comments on the Commission Roadmap regarding the development of a monitoring framework for the Circular Economy. Brüssel.

[33] Wilts, H.; Berg, H. (2017): in brief 04/2017. Digitale Kreislaufwirtschaft. Die Digitale Transformation als Wegbereiter ressourcenschonender Stoffkreisläufe. Wuppertal Institut für Klima, Umwelt, Energie gGmbH (Ed.). Wuppertal.

[34] Brother (2017): Toner Recycling. URL: http://recycling.brother.eu/de/ – Accessed October 10, 2017.

[35] Samsung (2017): S.T.A.R. Programme. URL https://support-prc.samsung.com/star_b2b/pages/home.aspx – Accessed October 10, 2017.

[36] Otto, B. et al. (2016): White Paper Industrial Data Space. Digitale Souveränität über Daten, URL: http://www.industrialdataspace.org/publications/ids-whitepaper/ – Accessed October 10, 2017.

[37] Schlatt, V. et al. (2016): Blockchain: Grundlagen, Anwendungen und Potenziale. URL: https://www.fit.fraunhofer.de/content/dam/fit/de/documents/Blockchain_WhitePaper_Grundlagen-Anwendungen-Potentiale.pdf – Accessed October 12, 2017.

[38] Clausen, U.; Dörmann, J.; Kopka, J.-P. (2017): Konzepte für die Kreislaufwirtschaft: Aktuelle Entwicklungen im Bereich des Baustoffrecyclings. In Wolf-Kluthausen, H. (Ed.): Jahrbuch Logistik 2017, S. 22-24. Wuppertal.

[39] Ford, S.; Despeisse, M. (2016): Additive Manufacturing and sustainability: an exploratory study of the advantages and challenges. In: Journal of Cleaner Production 137, S. 1573-1587. Elsevier.

[40] ten Hompel, M.; Henke, M. (2014): Logistik 4.0. In Bauernhansl, T.; ten Hompel, M.; Vogel-Heuser, B. (Ed.): Industrie 4.0 in Produktion, Automatisierung und Logistik. Springer Vieweg. Wiesbaden.

[41] Auffermann, C.; Kamagaev, A.; ten Hompel, M.; Vastag, A.; Verbeek, K.; Wolf, O. (2014): Scientific Paper. Cyber Physcal Systems in Logistics. URL: http://www.effizienzcluster.de/files/7/787/851_thesenpapier_cps_en.pdf – Accessed April 27, 2018

[42] Bauernhansl, T. (2014): Die Vierte Industrielle Revolution – Der Weg in ein wertschaffendes Produktionsparadigma. In Bauernhansl, T.; ten Hompel, M.; Vogel-Heuser, B. (Ed.): Industrie 4.0 in Produktion, Automatisierung und Logistik. Springer Vieweg. Wiesbaden.

[43] Tüllmann, C.; ten Hompel, M.; Nettsträter, A.; Prasse, C. (2017): Whitepaper Social Networked Industry ganzheitlich gestalten. In ten Hompel, M.; Henke, M.; Clausen, U. (Ed.): Schriftenreihe Future Challenges in Logistics and Supply Chain Management. Dortmund.

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