Market Analysis for Plastic waste recovery by regional blockchain networks

Project: Plastic waste recovery by regional blockchain networks

January 2019

Authors/Partners:

Wuppertal Institute
University of Bologna
Climate Blockchains Innovation Centre

Climate-KIC is supported by the EIT, a body of the European Union

Contents

1. Introduction

This working paper regards a market analysis for plastic waste recovery by regional blockchain networks which also marks the title of the underlying project. The analysis has a focus on Germany but also identifies and investigates the markets globally to search for related ideas to learn from or for existing competitors.

The basic idea behind this is grounded on the observation that many small to medium-sized companies (SMEs) create and command secondary plastics materials (e.g. by-products, left overs or small unused amounts of primary material) in amounts that are too small to be sold to secondary markets with a sensible margin. However, a cooperation on selling secondary plastics material could create the relevant scales needed or exchanging of such materials for further use could be enabled.

To create such a cooperation it is however important to safely and reliable store data on the quantity, quality, whereabouts, etc. of the material. Such knowledge is crucial to create trustworthy markets for high quality secondary materials – only secondary plastics of complete purity in material and colour can be reused in high value applications. Blockchain may provide the technology that enables and provides a trustworthy tracing and tracking to allow for safe distribution and commissioning of secondary plastics materials.

The following analysis is divided into three parts. Part 1 (chapters 2 and 3) defines and delineates blockchain technology and investigates into its aptness for the application envisioned here. Part 2 (chapters 4 to 6) analyse the German plastics industry, identifies potential regional hot spots and provides a glimpse into this industry's future. Part 3 contains an analysis of 14 existing material oriented blockchain applications. This analysis targets to identify role models and competitors and seeks to derive implications for the endeavour planned here.

Climate-KIC is supported by the EIT, a body of the European Union

2. Blockchain – a distributed ledger[1]

2.1 Definition

Blockchain is "an incorruptible digital ledger of economic transactions that can be programmed to record not just financial transactions but virtually everything of value" (Tapscott and Tapscott, 2016). An anonymous online ledger that uses the data structure to simplify the way in which we conduct transactions, blockchain allows users to participate in the ledger securely without a third-party intermediary (Dhar, 2017). In other words, it is a distributed ledger or a list of transactions across a peer-to-peer network. Data on a blockchain network is stored in a fixed structure called a 'block' and many 'blocks' form a chain of transactions. Thus, this technology is named 'blockchain'.

2.2 Characteristics of blockchain technology

As a transaction processing technology, blockchain, as with Bitcoin, any banking system or Customer Information Control System, can track transactions across a network and update accounts and payments. Differentiating blockchains from prior transaction processing technologies are three characteristics: (a) distributed ledger; (b) smart contracts; and (c) consensus algorithm (Brody, 2018).

(a) Distributed ledger

Most transaction systems maintain a single, centralised copy of transactions and accounts. In contrast, blockchain propagates the transactions and accounts across all the key points in the network, which means every location (node) in the network has all the necessary *data storage* to function autonomously. Tempering with transactional data is nigh impossible owing to the massive amount of copies everywhere. Beside tracking and processing the transactions with virtual time-stamps ('*hash*'), blockchain makes it possible to take anything which can be digitally represented and turn it into a tradable, saleable asset simply, securely and least costly.

(b) Smart contracts

The concept of smart contracts, alternatively known as 'programmable ledger', is embedded in the functionality of blockchain technology. Blockchain enables any participants to exchange digital agreements alongside economic value on a *peer-to-peer* basis. These agreements are then distributed across all the network nodes and enforced automatically. Smart contracts result in an elegant integration of real-world actions with the online exchange of value and payments.

(c) Consensus algorithm

Blockchain approves and records transaction through a process called 'consensus algorithm'. Blocks or groups of transactions are batched together and distributed for approval across all

[1] Prepared by Alastair Marke (Blockchain Climate Institute) in cooperation with Alberto Bellini (University of Bologna) and Holger Berg (Wuppertal Institute)

nodes in the network. Where there is conflict of 'truth', the version backed by the majority of the network nodes rules. The algorithm used in blockchain reduces the dependence on humans to verify the transactions. Consensus algorithm renders this system immutable and remarkably resilient to cyberattack because any attacker must compromise the majority of the network instead of only a single point of failure in an intermediary. This feature makes the system stronger as the network grows larger.

The control of a blockchain network depends on the type of blockchain, which ranges from permissioned (where the verification blockchain is pre-selected by a central authority or consortium) to permission-less (where anyone can participate in the verification process). At present, it is the permission-less blockchain that supports Bitcoin, which has drawn media attention.

2.3 Blockchain and cryptography

In fact, distributed database management systems (DDBMS) has been in existence since the 1990s. Current DDBMS processes huge amounts of structured and unstructured data for businesses through consensus mechanisms such as Paxos and Raft that controls read/write permissions and establishing secure communication channels among participants. Common applications of this technology include NoSQL, NewSQL and Hadoop databases. Nonetheless, these protocols assume that every participant transacts in good faith with private networks under a centralised authority which acts as the source of trust.

Common to blockchain, or a distributed ledger, and DDBMS protocols is the maintenance of a consensus about the existence and status of a shared set of facts. (See Section 2.2(c)) However, blockchain is not reliant on this assumption of good faith. Blockchain maintains consensus by leveraging strong cryptography to decentralise authority. It differs from generic DDBMS in two ways:

i. The control of the read/write access is truly decentralised; and
ii. The integrity of data can be assured in adversarial environment without the necessity of employing trusted third parties.

In regulated environment, distributed ledgers function in a similar way traditional DDBMS does, but they can benefit from the robust cryptography feature to enforce auditing, accountability and automation of existing business transaction systems (Meunier, 2018). Cryptography, therefore, is a key technology supporting a blockchain network.

Cryptography is not a new technology, but when blockchain combines it with data storage supporting distributed ledger (See Section 2.2(c)) and peer-to-peer protocols supporting smart contracts (i.e. smart economic rules) (See Section 2.2(b)), such suite of technologies can create revolutionary decentralised markets which have never existed before. That is the transformative power of blockchain technology.

2.4 Pitfalls and limitations of blockchain technology

Notwithstanding the transformative power of blockchain technology to the marketplace, it is not necessarily the cure-all panacea for all the world's problems. Noteworthy are several pitfalls below:

(a) Energy consumption

To unleash the full power of blockchain for a wide range of business purposes, energy efficiency is of paramount importance as blockchain is consuming an excessive amount of computing power (i.e. energy). The mechanism of consensus algorithm relies on proof-of-work, also known as 'mining', which is the most energy-consuming process especially true of bitcoin. It is the process by which computers solve complex mathematical riddles to perpetuate the blockchain and garner new bitcoin. The computers race against each other to be the one to validate the next block of transaction data and capture new coins. As more computers mine bitcoin when its price was mounting, the mathematical problems become more difficult to solve and require more computing power. Blockchain that runs on this algorithm could consume more energy than Argentina by the end of this year, according to a projection by Morgan Stanley (Rapier, 2018).

(b) Benefits invisible for end users

Despite its potentially revolutionary applications, the complexity of blockchain networks signifies that one must make a considerable effort to understand the principles of encryption and distributed ledgering behind blockchain before one can see the business case of adopting blockchain in an organisation's daily operations. Benefits are invisible and intangible for end users unless there is a severe trust problem with the intermediaries in current transaction systems.

(c) Slow and cumbersome process

The complexity of blockchain networks also signifies that blockchain-supported transactions can take longer time to process than traditional payment systems such as cash or debit cards. For example, bitcoin transactions can take a couple of hours to finalise, which is an inherent problem for businesses engaged in simple or small-amount transactions. The slow and cumbersome payment verification process can deteriorate as the blockchain networks grow in size and hence, the number of computers accessing and writing to the network multiplies exponentially.

Hype for blockchain intensified across industries in 2015-16. Not only had blockchain been on the cover of mainstream periodicals including *The Economist* in October 2015, but also it has attracted over US$1 billion investment from venture capitalists (Zuckerman, 2018); and generated thousands of start-ups and an entire new fintech industry. The 'blockchain mania' has also neglected some limitations of this technology, including:

- *Connectivity between digital record and real-world property* – Although digital records on a blockchain are supposed to be immutable and verifiable, it is difficult for humans to discern which digital record is attached to which real-world property (Tucker and

Catalini, 2018). Blockchain cannot guarantee verification is conducted correctly unless a small chip using the Internet of Things (IoT) technology that links every real-world object with its digital record becomes the norm.

- *Incapacity to overcome human errors* – Blockchain excels in accurate automated recordkeeping, however, there is still a margin for human error beyond the capacity of blockchain to address. For example, the application of blockchain technology to track boxes in warehouse cannot prevent humans from entering incorrect information or scanning the same box twice, which falsifies the digital record by accident (Paulsen, 2018). The use of Artificial Intelligence (AI) technology may be a solution to this constraint.

- *Fallibility and humanity of smart contracts* – Smart contracts are supposed to safeguard against the proceeding of transactions until the terms have been satisfied, but they will never be the same as a lawyer or third-party individual who examines the terms to reassure all parties that the transaction is fully legitimate. This third-party individual will be substituted by 'bots', which automate every transaction without 'humane' consideration of other factors not coded in the smart contract. This problem could be dangerous to users under certain circumstances.

2.5 Major barriers to extensive adoption of blockchain technology

Conducted in April-May 2018, PwC's Global Blockchain Survey interviewed 600 respondents from 15 territories. Respondents were business executives with technology responsibilities, 31% of which work in organisations with revenues of US$1 billion or more. The top three barriers cited are: regulatory uncertainty (48%), lack of trust (45%) and ability to bring network together (44%) (Hankin, 2018; PwC, 2018). (See Figure 1)

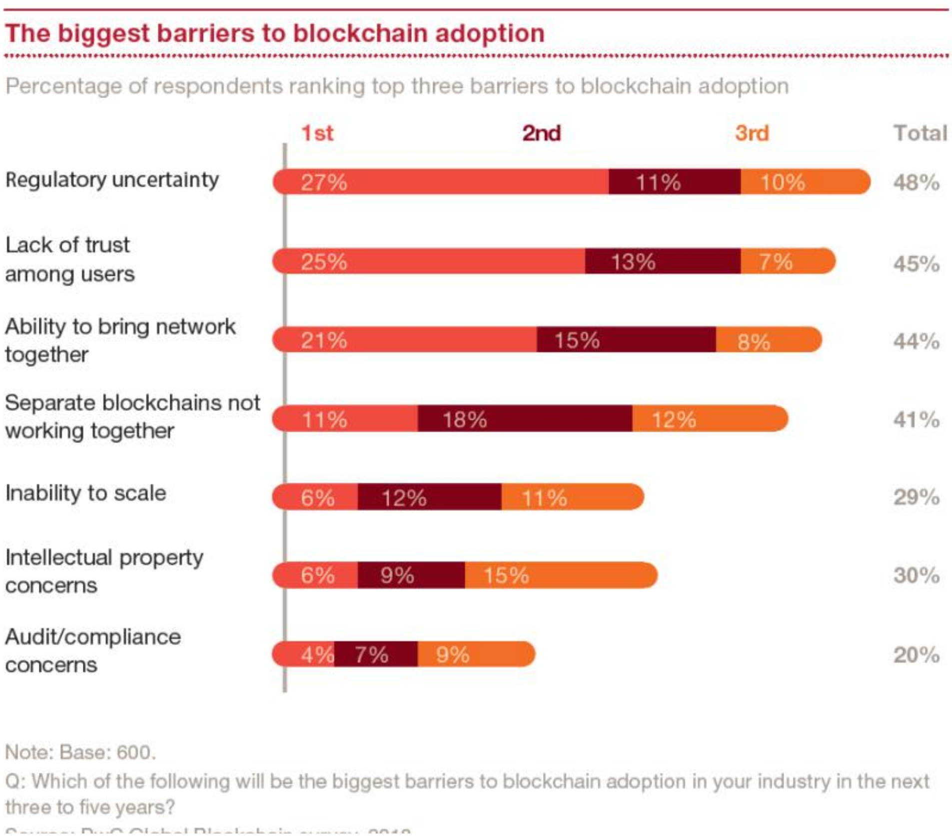

Figure 1 Major barriers to blockchain adoption (PwC Global Blockchain Survey 2018)

[1] **Regulatory uncertainty:** The majority of regulators are still reconciling themselves to blockchain and cryptocurrency. Many businesses have commenced studies on the application of blockchain particularly to financial services, however, the overall regulatory environment remains unsettled. Clear regulations – rules, guidelines and codes – in the crypto space will bring much needed certainty to stakeholders and de-risk their investment in blockchain applications without the fear of scams (Hankin, 2018).

[2] **Lack of trust (invisibility):** Second to regulatory uncertainty as the top concern for executives as they consider this decentralised ledgering technology is, ironically, 'trust' in spite of the hype over the past few years. Blockchain is supposed to engender trust. "But in reality, companies confront trust issues at nearly every turn. For one, users must build confidence in the technology itself," according to the Survey (PwC, 2018). Nowadays IBM makes computers smaller than salt grains. All-inclusive in a small device, a computer comprises phone, passport, light switch at home and everything run on processing power and connected to the internet. Yet, the advanced technologies underpinning all these functionalities are invisible and incomprehensible to most people. Adopting blockchain results in revolutionary changes but they are so subtle that users do not notice it. Trust is difficult to be built on invisible benefits (Goke, 2018).

[3] **Ability to bring networks together (interoperability):** Blockchain applications need the same plug-and-play infrastructure on which to function. Today a company which intends to adopt blockchain need to invest in retraining a dedicated team of seasoned developers regarding new programming languages they have to use to develop a custom-coded solution. Almost all blockchain applications currently require users to either run a blockchain node or install a 'light node'. As with bitcoin blockchain network, there are complicated rules in place to make the network operate as intended. But these complicated rules impede the expansion of blockchain technologies among potential users. Without an easily accessible software development kit, blockchain innovation cannot reach critical velocity as companies find it too costly to integrate their existing transaction systems (Goke, 2018) and make them interoperable with those of their suppliers who have not adopted blockchain yet.

2.6 Reducing energy consumption of blockchain applications

As described in paragraph 2.4(a), under the 'consensus mechanism' (i.e. a proof-of-work'). the 'mining' process of cryptocurrencies (e.g. Bitcoin) associated with many blockchain applications consumes an excessive amount of energy, which is an oft-quoted impediment for the use of blockchain. Such energy-consuming mining process may render blockchain applications unsustainable given its energy cost being high and; transaction processing speeds not being in pace with the growing volume of transactions on blockchain networks. If the full potential of blockchain technology is to be unleashed for a variety of business transactions, the key is 'green' – translated as 'energy efficiency'.

To this end, many technologies are exploring alternatives to minimise the energy consumption of blockchain solutions. R3 and Ethereum have recently built some energy-efficient permissioned blockchains, which can process considerably more transactions per second at minimal cost, while accommodating an ever-expanding user base. MIT, Cornell, IBM and Intel are also developing 'green' blockchain solutions.

A major alternative that could replace 'proof-of-work' or 'mining' is 'proof-of-stake'. Whereas proof-of-work rewards participants for spending computational resources, blockchains that adopt proof-of-stake would select validators based partly on the size of their respective monetary deposits – their stake, and a lottery system. In other words, the more coins one owns, the better chances of one being chosen to mine them. The new mechanism would be significantly more energy-efficient, though this concept has not been proven at a large scale yet and hence, further tuning is necessary. Proof-of-stake may also be integrated with renewable energy investment opportunities. Conceptually, validating computers may be chosen based on the owner's purchasing record of renewable energy certificates (REC). This could energise many related cryptocurrency systems and scale up renewable energy development in many countries.

Considerations should be given to adopting 'proof-of-stake' as the new consensus mechanism for environment-related blockchain solutions such as those for the reduction of plastic waste in order for the users to 'walk the talk'.

3. Blockchain applications for circular economy

3.1 Expanded roles of consumers in new circular economy

Today there are a myriad of digital platforms on which consumers avail their assets and skills to the market such as eBay and Airbnb subject to two constraints. First and foremost, these business models are third-party centralised marketplace systems that control the flow of information and currency among participating parties. Batista (2017) also suggests the second constraint for consumers, that is, many circular economy business models (CEBMs) are still principally firm-centric. These models relegate the end consumers to roles no more than using, sharing and/or separating products or waste for reuse or refuse collection, which squanders consumers' capabilities and endeavours an effective circular economy should co-opt.

Co-opting consumers capabilities can accelerate the global shift towards circular economy by transforming the regenerative product-service system. The critical question lies in how consumers can be empowered to engage and participate more actively in product reuse and recovery processes. Blockchain may be the missing link that enables such consumer empowerment for achieving circular economy tomorrow.

The advent of blockchain technology provides an unparalleled driver for peer-to-peer CEBMs to thrive. Blockchain-supported platforms enable peer-to-peer transactions without any middlemen. It means consumers can transact and pay each other directly and securely through a decentralised or globally distributed network. Trusted peer-to-peer models allow consumers to circulate and recapture value from their underused assets to close the loop of manufacturing economy. The opportunities created by blockchain technology are unlimited, including the value one can attach to a cryptocurrency, or 'coin', in a blockchain marketplace.

Climate-KIC is supported by the EIT, a body of the European Union

3.2 Emerging blockchain applications for circular economy

Eikmanns (2018) groups blockchain applications for promoting circular economy into four categories: (1) Resource efficiency enhancement; (2) Resource tracking; (3) Resource pricing; and (4) Complementary currency. Table 1 summarises the opportunities which blockchain technology offers under the four application categories.

Table 1: Categorisation of opportunities from blockchain applications for circular economy

Application category	Opportunities from blockchain technology	Examples
Resource Efficiency enhancement	To make sharing economy models attractive by removing middlemen and/or creating a blockchain-based identity system To enable direct financing of sustainable projects	Sharing economy: Arcade City Lazooz
Resource Tracking	To record transactions openly, indefinitely and immutably, enhancing the transparency and trust in the information provided To empower consumers in their consumer decisions	Certification: PEFC FSC BHP Billiton Resource tracking: IBM collaboration with Nestlé, Unilever and Walmart
Resource Pricing	To create more efficient credit management platforms To create a cap-and-trade system considerably automatized with smart contracts against politicians chasing their political agendas	Carbon credit management platform: IBM-Energy Blockchain Lab collaboration
Complementary Currency	To create financial accounting and macroeconomic systems with different rules from the current monetary systems	Cryptocurrencies: Solar Coin Eco Coin

Application category	Opportunities from blockchain technology	Examples
		Earth Dollar BitNatura

[1] Resource efficiency enhancement: Application of blockchain technology can help enhance resource efficiency at societal level. The introduction of IoT – a network of smart devices – to various materials will further increase resource efficiency. Peer-to-peer transactions without any intermediaries like eBay (including the sharing of under-utilised assets such as ride-sharing application of the Arcade City; and direct non-bank lending to finance sustainable assets) can accelerate the progress towards a sharing economy and hence, circular economy.

[2] Resource tracking: Blockchain technology tracks transactions (i.e. flows of materials) and creates tamper-proof validation systems without the necessity of centralised authorities. Not alterable, transactions are infinitely and transparently recorded, which increases public trust in the data stored on a blockchain.
For example, PEFC (Programme for the Endorsement of Forest Certification) aims at blockchain to track the origin of timber. Provenance, a start-up engaged in supply chain transparency, is designing a blockchain system able to track and trace in real time all second-hand materials, including the dimensions of quality, quantity and ownership, along the entire supply chain with a digital passport for every product. The seamless digital records will make digital certifications, such as emission allowances or proof of origin records, to raw materials possible. Another example is BHP Billiton who is in partnership with Everledger to track the origins of diamonds to augment compliance with regulations governing 'blood diamonds'.

Blockchain is conducive to increasing transparency of the global supply chains, which in turn, discourages individual manufacturers from concealing any details of their supply chains. It also reinforces the circularity and sustainability of the economy.

[3] Resource pricing: Blockchain can support the implementation of resource pricing systems through cap-and-trade or Pigouvian taxes. It offers a cradle for a cap-and-trade system, that is, a regulatory instrument comprising the issuance of limited credits to use a certain resource and the creation of a market to trade these credits. A blockchain-supported cap-and-system will be an efficient credit management platform. For instance, the IBM is collaboration with the Energy Blockchain Lab to introduce blockchain to carbon credit management in China, which will increase the transparency, auditability and credibility of the Chinese Emissions Trading Scheme.

A system automated with smart contracts can avert policymakers from interfering the marketplace in pursuit of any self-serving political agendas. The full potential of blockchain in this aspect can be fully exploited if AI is employed to create a market stability mechanism that coordinates the issuance of credits to avoid disequilibrium of resource credits and to maintain the market prices in a pre-defined range without any arbitrary administrative interventions.

[4] Complementary currency: Blockchain allows the implementation of complementary currency systems which incentivise sustainable behaviours by individuals and businesses through 'tokenisation'. 'Tokens' will reward their participation in the new circular economy with customised currency and work units, which can address the weakest link of the peer-to-peer, crowd-sourced and sharing economy. Cryptocurrencies, though, should not intend to replace but to complement fiat currencies.

EcoCoin, for instance, envisions a community-based cryptocurrency which allows the EcoCoin Community to decide what to support and purchase on a case by case basis, despite its limited ecological impact. EarthDollar intends to transform the entire economic system and facilitate the attainment of the Sustainable Development Goals by supporting Natural Capital Accounting rather than conventional financial accounting. These cryptocurrencies are, however, possibly not asset-backed and of bottom-up approach in nature. Ultimately, the world needs a top-down approach through government-backed cryptocurrency that carries both financial and socio-environmental values.

3.3 Mapping of blockchain applications for waste recovery

Table 2 below maps 14 blockchain applications for waste recovery against the four categories suggested in Eikmanns (2018).

Table 2: Mapping of blockchain applications for waste recovery and recycling

Category of application functions	Blockchain application	Provider (Country)	Target materials
Resource Efficiency enhancement	Excess Materials Exchange	Excess Materials Exchange (The Netherlands)	Any excess materials and under-used products
	ShareRing	ShareRing (Australia)	Different kinds of products and services
	IBM Blockchain Platform	IBM (US) / Plastic Bank (Canada)	Plastics
Resource Tracking	Circularise	Circularise (The Netherlands)	Waste electronic devices
	European waste	Dutch Ministry of	Waste moved

Category of application functions	Blockchain application	Provider (Country)	Target materials
	transportation on blockchain	Infrastructure & Water Management (The Netherlands)	between Netherlands and Belgium
	Foodchain	Foodchain Spa (Italy)	Food waste
	Troventum	Troventum Limited (Malta)	Solid recyclable household waste
	IBM Blockchain Platform	IBM (US) / Plastic Bank (Canada)	Plastics
Resource Pricing	Cycled	Cycled (Norway)	Household waste
Complementary Currency	Augoraa Tech Lab	Ethereum Foundation (Switzerland)	Plastic waste
	Cycled	Cycled (Norway)	Household waste
	Zafeplace blockchain platform	Zafeplace / Empower (Norway)	End-of-life plastics
	NatureCoin	NatureCoin (Canada)	Disposable waste (including plastics, tins and cans)
	IBM Blockchain Platform	IBM (US) / Plastic Bank (Canada)	Plastics
	Recreum	Ethereum Foundation (Switzerland)	Glass, plastic, aluminium, used batteries, paper, wood
	RecycleToCoin	BCDC.Online Limited (UK)	'Single-use' plastic bottles and aluminium cans
	Swachhcoin	Swachhcoin (India)	Recyclable waste from household and

Category of application functions	Blockchain application	Provider (Country)	Target materials
			industries

None of the blockchain applications identified delivers all the four possible functions above. The mapping exercise in Table 2 demonstrates that most of them concentrate in the use of complementary currency or ‘coin’ to reward stakeholders for participating in various stages of the waste recycling or recovery process. Besides, there are several blockchain applications designed to enhance resource efficiency and track resource along the value chains for increasing the recoverability of waste materials. Nonetheless, it is observed that only one blockchain application which is deemed close enough to waste resource pricing – supposedly the most cost-effective mechanism to achieve circular economy.

4. Case Study: application of blockchain in the reduction of plastic waste: ‘The Plastic Bank’

Among other applications, *IBM-Plastic Bank blockchain platform* is the only one which delivers to different extent three out of the four application functions: complementary currency, resource tracking and promoting resource efficiency. The case of ‘The Plastic Bank’ could serve as a case study for this Pathfinder Project.

Business goals

Founded in Vancouver in May 2013, The Plastic Bank is a social enterprise which tackles ocean plastic waste and, simultaneously, global poverty. In collaboration with *IBM* and *Cognition Foundry*, The Plastic Bank enlists the help of collectors from amongst the world’s poorest communities to gather plastic waste in localities where recycling infrastructure is inadequate and offers life-changing goods in return. It redefines the value of plastic waste, interrupts its flow to the ocean and channels it to corporations as secondary raw materials in their new products.

As a result, The Plastic Bank has created secure asset-backed rewards to underpin the exchange of plastic waste for goods. Not only has it sparked massive expansion in operations, but also it has alleviated poverty by turning the most disadvantaged into recycling entrepreneurs (IBM, 2018).

4.1 Blockchain-based business model

The Plastic Bank is a social enterprise with a non-profit orientation. It encourages citizens to collect and deliver plastic waste to its local processing centres. In reciprocity, citizens earn tokens that are either tied to the US dollar and can be traded for cash at dedicated non-profit stores or that tokens that function as vouchers for daily essentials such as food, sustainable cooking fuel, high-efficiency stoves, phone-charging credits, school tuition, medical insurance and Wi-Fi, etc. No matter which of the two types of tokens is claimed as reward, the collected plastic that is handed over to the collection points and local processing centres is grinded into pellets which are resold to manufacturers for re-use in packaging or new products as sustainable alternative to virgin plastics. This is one way for The Plastic Bank to earn money or respectively to fund the tokens and trading (Inverse 2019). Other means to draw on financial supports consists of donations (one-time, monthly/annual subscriptions), an own “merchandise shop” (The Plastic Bank 2019a) and the opportunity for private people or businesses to “offset their own plastic footprint” though buying a “plastic neutral certificate” at different levels, which founds “*the collection of an equivalent amount of ocean bound plastic*” through the “Social Plastic Ecosystem” of The Plastic Bank (The Plastic Bank 2019b). The other side of their business model is more focussed on B2B contacts and sales of the collected and processed secondary plastics. The most well known international corporation supporting The Plastic Bank through buying and utilising the generated secondary plastics are Henkel, Shell and Marks and Spencer (The Plastic Bank 2019c). Unfortunately there are no figures published on the costs or revenues from this business model but the following rather general distribution of their earnings: The Plastic Bank is offering so called “Social Plastic® Collection Credits” (SPCC) where 1 SPCC comes at a price/value of US$ 0.44 and equals and guarantees the collection and recycling of 1 kg plastic waste However, 70% of the income generated through purchases of SPCC are said to stay within the local economy of the regions that The Plastic Bank is active in (The Plastic Bank 2019d).

Started with a paper-based transaction record system, The Plastic Bank today partners with *IBM Blockchain* technology to rack the whole value chain of recycled plastic, from collection, credit and compensation, to delivery to manufacturers for re-use. The social enterprise has also developed a blockchain-powered token reward system as a complementary currency and a mobile phone app as an exchange platform that underpins the compensation of valuable commodities for people participating in plastic waste recycling. A token reward system based on blockchain monetises plastic waste and records transactions at the micro-level. The accumulation of these micro-transactions prompts the issuance of digital tokens that these plastic waste collectors can use to redeem useful goods safely.

Attributable to the singularity and irrefutability of hyperledger, The Plastic Bank has gained complete faith of people in the most disadvantaged countries, manufacturers and corporate partners in the integrity of its enterprise (IBM, 2018; Mok, 2018).

4.2 Replicability of business model to the plastic packaging industry in Europe

4.2.1 Waste from plastic packaging

EU countries do not need to cope with ocean plastic waste of the same magnitude to that in less developed countries, notwithstanding, many EU countries are facing a similar problem of ever-growing amount of plastic waste overloading their landfill sites every day. In the EU, on average, 31kg of plastic packaging waste is produced per person per year (ranging from 12kg in Croatia to 60kg in Ireland), which results in 15.8 million tonnes of plastic packaging waste generated in the EU in one year. This amount has grown steadily for all member states over the last decade (Eurostat, 2018).

Five everyday packages made of unrecyclable plastics:

1. Margarine and ice-cream tubs
2. Microwave meal and meat packaging
3. Fruit and vegetable punnets
4. Yoghurt pots
5. Bakery goods trays

In the EU, only 40% of plastic waste is recycled, with the highest concentration reported in Slovenia (63%) and the lowest in Finland (24%) (Eurostat, 2018). It means around two-thirds (approximately 169,145 tonnes) of plastic found in 525,000 tonnes of packaging pots, tubs and trays used by households is unrecyclable. Packaging for food consumed by households daily is often made of a variety of polymers which need to be disintegrated to remove 'low-grade' and non-recyclable polymers such as polystyrene. For examples, fruit and vegetable punnets are usually made from three different types of polymers, while different plastics are used in the body and lid of a yogurt pot. Microwave meals are often encased in predominantly black plastic material for aesthetic reasons, but black is the only colour that cannot be scanned and sorted by recycling machines easily, which often results in these recyclables going to the landfills (LGA, 2018).

4.2.2 Youth poverty

On the other hand, poverty among young people is not uncommon in the EU countries, as the youth unemployment rate in has remained high since 2008. As of May 2018, the average youth employment rate in the Eurozone stood at 16.8%. There were 11 member states in which the youth unemployment rate was above Eurozone average, ranging from 18.4% in Finland to 31.9% in Italy, 33.8% in Spain and up to 43.2% in Greece (Statistica, 2018).

4.2.3 Replicability of The Plastic Bank model

Both plastic waste and poverty problems in EU countries have created similar conditions under which the business model of The Plastic Bank should be replicable in the interest of environmental and social sustainability. In the environmental dimension, the same blockchain-based system that trades and tracks these 'social plastics' to prevent them from going to oceans or landfills. In the social dimension, the blockchain system rewards people's participation in collecting and recycling plastic waste though (government-backed) digital tokens. Blockchain can kindle the entrepreneurial spirit of (unemployed) young people by making many small-scale, low-entry-threshold recycling and related enterprises commercially viable even in small towns. These regional blockchain networks, in turn, create job and wealth to revitalise local economies across the EU.

Yet, the transformative power of this blockchain-based business model as a plastic waste recovery regional network in the EU cannot be fully unleashed unless the EU provides the three conditions below:

(a) Governments ban a smorgasbord of low-grade and unrecyclable plastics as well as scan-unfriendly colour from being used in packaging materials;
(b) Manufacturers contribute to the cost of collection and transportation; and
(c) Governments and manufacturers agree to an industry-wide plastics cap-and-trade scheme.

As blockchain can track a product's biological or technical components, the industry can enforce a sophisticated cap-and-trade scheme through setting quotas and levied prices on the use of virgin, low-grade and unrecyclable plastics. For example, the use of packaging materials made of virgin, low-grade or unrecyclable plastics are subject to an annual quota and a 'plastic tax'. The composition of these packaging materials can be recorded on a smart contract which triggers the 'plastic tax' when manufacturers do not reuse these packaging materials until the point of full degradation. The prices of these virgin or used unrecyclable plastics will rise gradually alongside decremental changes to the quota.

The complexity of trading networks in major cities in the EU implies the need to develop further this blockchain plastic waste recovery network with Artificial Intelligence. Relevant sub-sets of Artificial Intelligence to this realm include analytics, visual recognition and machine learning technologies that automate as per their potential value the identification and categorisation of plastic materials collected. All these features will make an unprecedentedly powerful regional network that materialise a paradigm shift to manage plastics and, ultimately, a truly circular economy.

References

Batista, L. (2017) *Empowering consumers in the circular economy. Is blockchain the missing link?*, *CCEG Blockchain UN Lab*. Available at: https://mypad.northampton.ac.uk/cceg/2017/03/23/empowering-consumers-in-the-circular-economy-is-blockchain-the-missing-link/#.W8NN32hKhPY (Accessed: 10 October 2018).

Brody, P. (2018) 'How blockchains will industrialise a renewable grid', in Marke, A. (ed.) *Transforming climate finance and green investment with blockchains*. First. London: Elsevier Publishing.

Dhar, K. (2017) 'Don't know what's Blockchain technology? Let us explain', *Business Today*, March. Available at: https://www.businesstoday.in/sectors/banks/what-is-blockchain-technology-let-us-explain-bitcoin-banks/story/238438.html.

Eikmanns, B. C. (2018) *Blockchain: Proposition of a New and Sustainable Macroeconomic System*. Frankfurt.

Eurostat (2018) *How much plastic packaging waste do you produce?*, *Your key to European statistics*. Available at: https://ec.europa.eu/eurostat/web/products-eurostat-news/-/EDN-20180422-1?inheritRedirect=true (Accessed: 10 October 2018).

Goke, N. (2018) '7 Big Obstacles To Mass Adoption Of Blockchain Technology', *Medium*. Available at: https://medium.com/the-crypto-times/7-big-obstacles-to-mass-adoption-of-blockchain-technology-87740cdda9fe.

Hankin, A. (2018) 'Survey finds a surprising barrier to blockchain adoption', *Market Watch*, August. Available at: https://www.marketwatch.com/story/survey-finds-a-surprising-barrier-to-blockchain-adoption-2018-08-28.

IBM (2018) *The Plastic Bank: Tackling ocean plastic and global poverty with blockchain-based token rewards*, *IBM Case Studies*. Available at: https://www.ibm.com/case-studies/plastic-bank (Accessed: 12 October 2018).

Invers (2019) How IBM and Plastic Bank are using blockchain to boost recycling in Haiti, Available at: https://www.inverse.com/article/49158-how-ibm-and-plastic-bank-are-using-blockchain-to-boost-recycling-in-haiti?refresh=58 (Accessed 07 January 2019)

LGA (2018) *Two-thirds of plastic in packaging pots and trays is unrecyclable*, *Local Government Association News*. Available at: https://www.local.gov.uk/about/news/two-thirds-plastic-packaging-pots-and-trays-unrecyclable (Accessed: 11 October 2018).

Meunier, S. (2018) 'Blockchain 101: What is blockchain and how does this revolutionary technology work?', in Marke, A. (ed.) *Transforming climate finance and green investment with blockchains*. First. London: Elsevier Publishing.

Mok, K. (2018) *Plastic Bank using blockchain tech to monetize plastic waste*, *The New Stack*. Available at: https://thenewstack.io/plastic-bank-using-blockchain-tech-to-monetize-plastic-waste/ (Accessed: 12 October 2018).

Paulsen, I. (2018) 'Things blockchain can't do and won't solve', *The Chain*, July. Available at: https://thechain.media/things-blockchain-cant-do-and-won-t-solve.

PwC (2018) *PwC's Global Blockchain Survey 2018*. Hong Kong. Available at: https://www.pwccn.com/en/research-and-insights/publications/global-blockchain-survey-2018/global-blockchain-survey-2018-report.pdf.

Rapier, G. (2018) 'Morgan Stanley: Bitcoin could use more energy than Argentina this year', *Markets Insider*, January. Available at: https://markets.businessinsider.com/currencies/news/bitcoin-mining-could-use-more-energy-than-electric-cars-this-year-morgan-stanley-2018-1-1012823094.

Statistica (2018) *Youth unemployment rate in Europe as of May 2018*, *The Statistics Portal*. Available at: https://www.statista.com/statistics/266228/youth-unemployment-rate-in-eu-countries/ (Accessed: 10 October 2018).

Tapscott, D. and Tapscott, A. (2016) *Blockchain Revolution: How the Technology Behind Bitcoin Is Changing Money, Business, and the World*. London: Penguin Publishing Group.

The Plastic Bank (2019a) "Merchandise-Shop", Available at: https://plasticbank.teemill.com/ (Accessed 07 January 2019)

The Plastic Bank (2019b) "Plastic Neutral Gifts", Available at: https://www.plasticbank.com/plastic-neutral-gifts/#.XDM3AScxnuQ (Accessed 07 January 2019)

The Plastic Bank (2019c) "What we do", Available at https://www.plasticbank.com/what-we-do/#.XDNzjycxnuQ (Accessed 07 January 2019)

The Plastic Bank (2019c) "Social Plastic Collection Credits", Available at https://www.plasticbank.com/social-plastic-collection-credits/#.XDNYiScxnuQ (Accessed 07 January 2019)

Tucker, C. and Catalini, C. (2018) 'What blockchain can't do', *Harvard Business Review*, June. Available at: https://hbr.org/2018/06/what-blockchain-cant-do.

Zuckerman, M. (2018) 'VC investments in blockchain companies on track to exceed 2017's numbers', *Coin Telegram*, March. Available at: https://cointelegraph.com/news/vc-investments-in-blockchain-companies-on-track-to-exceed-2017s-numbers.

The Plastics Strategy by the EU Commission encourages EU members to reduce plastic waste through recycling and banning disposable plastics until 2030. In Germany for example, the plastic processing quantities and plastic waste quantities both show an increasing trend, which in return need to be even more put in the context of a circular economy to reach the goals of the Strategy. Against this background, blockchain applications can be seen as a lever to increase the resource efficiency of plastic production by giving the opportunity to track plastic waste or material flows. However, as the establishment of blockchains is significantly hampered by lack of trust relating to the technology but also to cooperation between the potential partners. However, blockchain could thus emerge and make sense in regional networks where plastic leftovers are saved and distributed between companies to prevent plastic waste and economize on the leftovers.

Germany lends it itself as an experimental ground for this as the country has a dense population of plastics related industries and companies. The following regional analysis of the German plastics market will give more insight into this. The study contains an overview of the current market situation of the plastic converting industry in Germany (chapter 1.), shows the geographical distribution of the sector (chapter 2.) and gives an outlook of the future development (chapter 3). From this, potential areas and industries where the concept may be applied can be identified.

5. Plastics converters industry in Germany - Current market situation[2]

5.1 Total market data

With a total revenue of 63.7 billion € in 2017 the plastics converting industry is a very important economic sector in Germany. The predominantly small and medium-sized industry is characterised by a diverse product range. Plastic is mainly used for packaging, construction supplies, engineering parts, semi-finished products and consumer goods. Also the medicine sector is using a wide range of polymeric products due to the aseptic - single use technology.

According to the latest numbers for the year 2017, the plastic converting industry of Germany is still growing. Market data from the German Association of Plastic Converters (GKV), considering companies with the number of employees equal or higher than 20, shows a positive trend for the relevant economical key indicators [GKV18].

Figure 2 Processing plastic converting in Germany 2017, Source: (GKV18)

Compared to the previous year (2016) the total processed quanitity of plastic material increased by 4.6 %, leading to a growth in revenue of 4.8 %. In accordance, also the number of employees and the number of companies increased by 1.9 % and 1.5 % respectively.

---

[2] This part of the study has be prepared by SKZ KFE gGmbH on behalf of the consortium.

5.2 Market data by material - processing quantities

According to the conversio study [CMS18] the total volume of plastic converted in Germany amounted to ~ 14.4 Mio. t in 2017 [CMS18]. Figure 3 gives the quantities processed by plastic types. Due to its low price and its good usability in the packaging sector, PE (LD and HD Polyethylene) is the most extensively used polymer (3.973 kt). The second most widely used polyolefin is PP (2.453 kt). PVC (Polyvinyl chloride) - the most important plastic in the construction sector – ranks third with 1.8 kt.

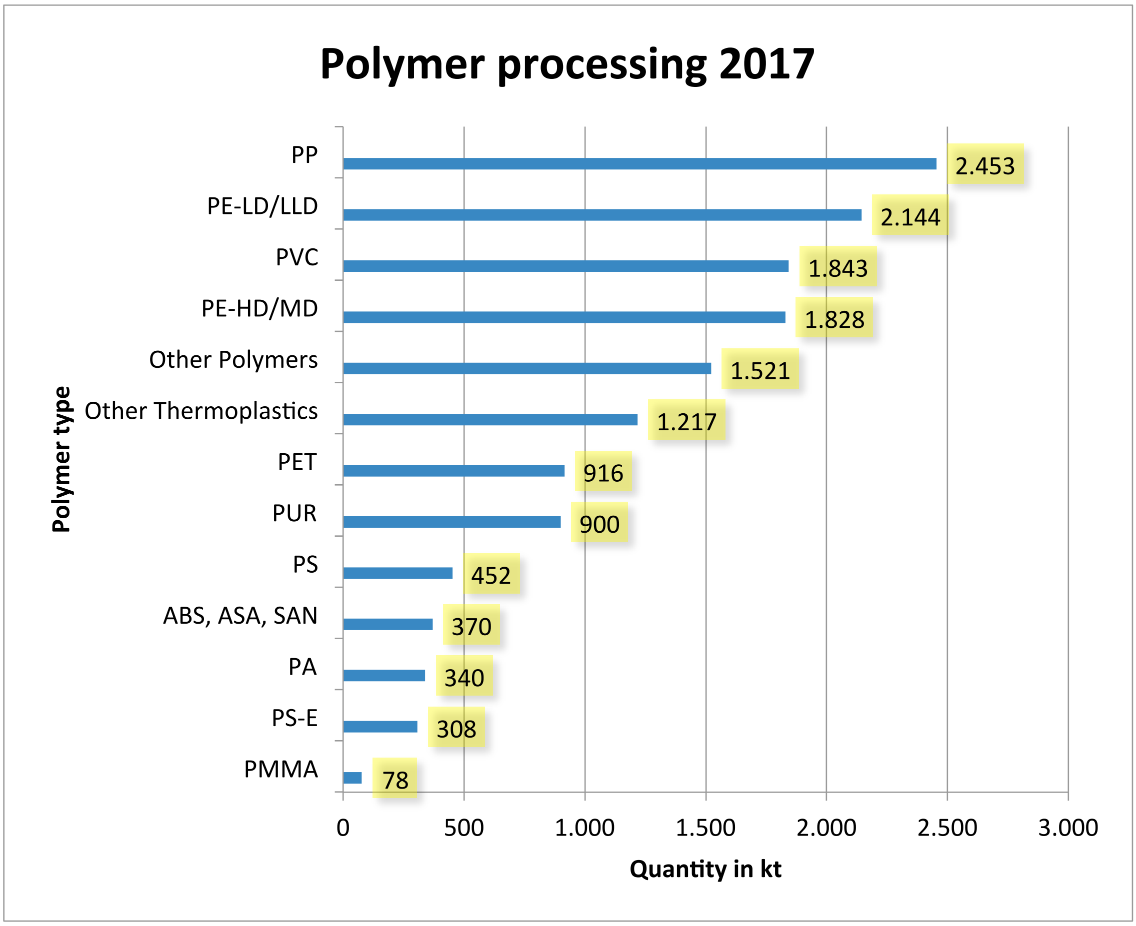

Figure 3: Polymer processing 2017; Source: [CMS18]

The quantity of individual polymers processed from 2011 to 2017 is shown in figure 4.

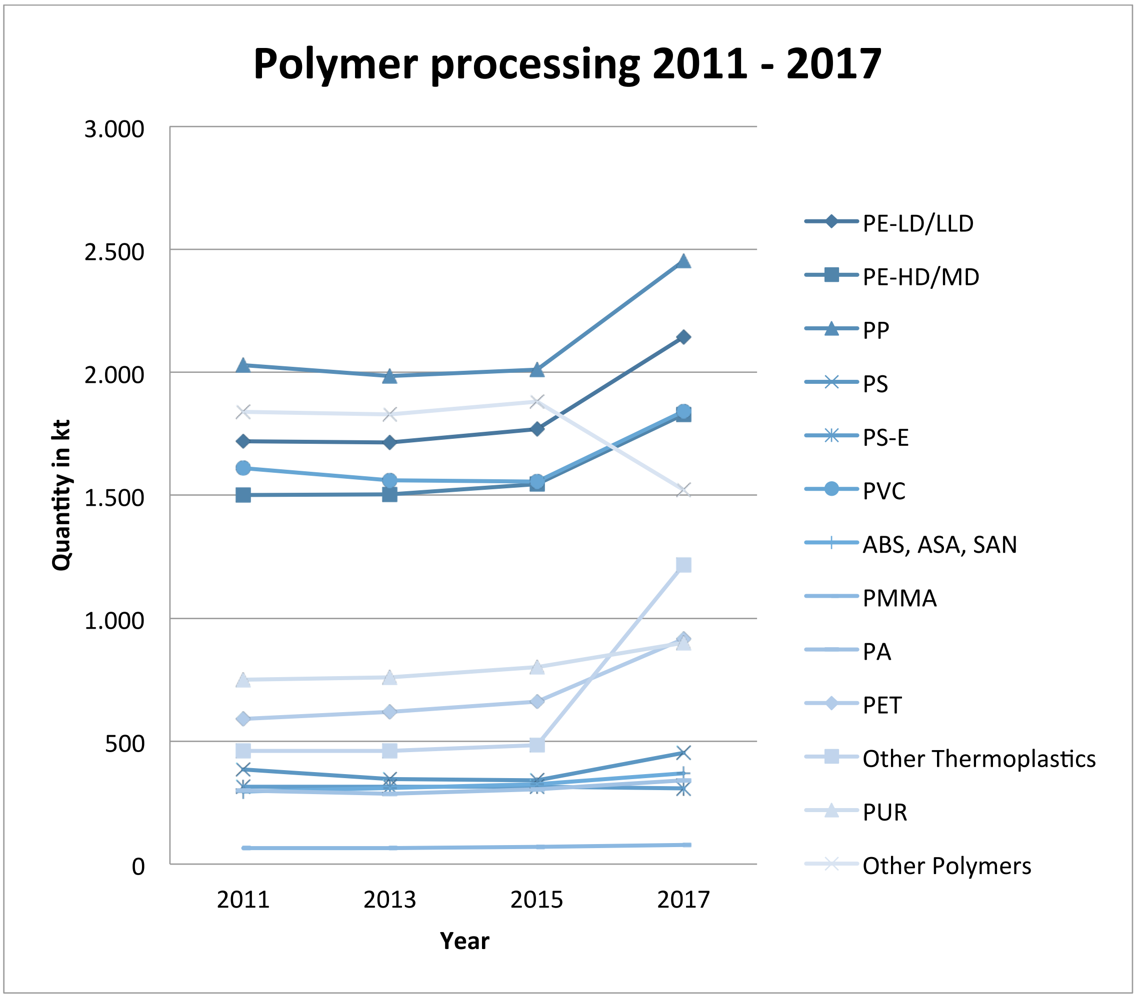

Figure 4: Polymer processing 2011-2017; Source: [CMI14], [CMI16], [CMS18]

Looking at the trend over the last 7 years, a significant increase is noticeable between 2015 and 2017 (figure 3). Except for PS-E (expandable polystyrene) and the bundled plastics, which suffered a decline of 2 respectively 19 %, the growth was at least 10 % for each polymer. In total, plastics have experienced a volume increase of 19 % in that period (table 3).

Table 3: Trend in polymer converting for the years 2015-2017; Source: [CMI16], [CMS18]

Polymer Type	Trend 2015-2017
PE-LD/LLD	□ 21%
PE-HD/MD	□ 18%
PP	□ 22%
PS	□ 33%
PS-E	□ -2%
PVC	□ 19%
ABS, ASA, SAN	□ 14%
PMMA	□ 11%
PA	□ 11%
PET	□ 39%
Other Thermoplastics	□ 151%
PUR	□ 13%
Other Polymers	□ -19%
Total (All Polymers)	□ 19%

5.3 Market data by industry sector – processing quantities

Polymers, mostly supplied as granules or powders by the chemical industry, are processed to semi-finished or finished products mainly by injection moulding and extrusion and to a less extent by calendering and blow moulding. Joining methods are gluing and welding.

Plastics continue to have a variety of applications. Figure 4 shows the processed quantities for the main areas of application. Packaging accounts for around 30 % of the processed plastic, followed by the construction sector at around 25 %, others at 15 % and automobile applications at 11 %.

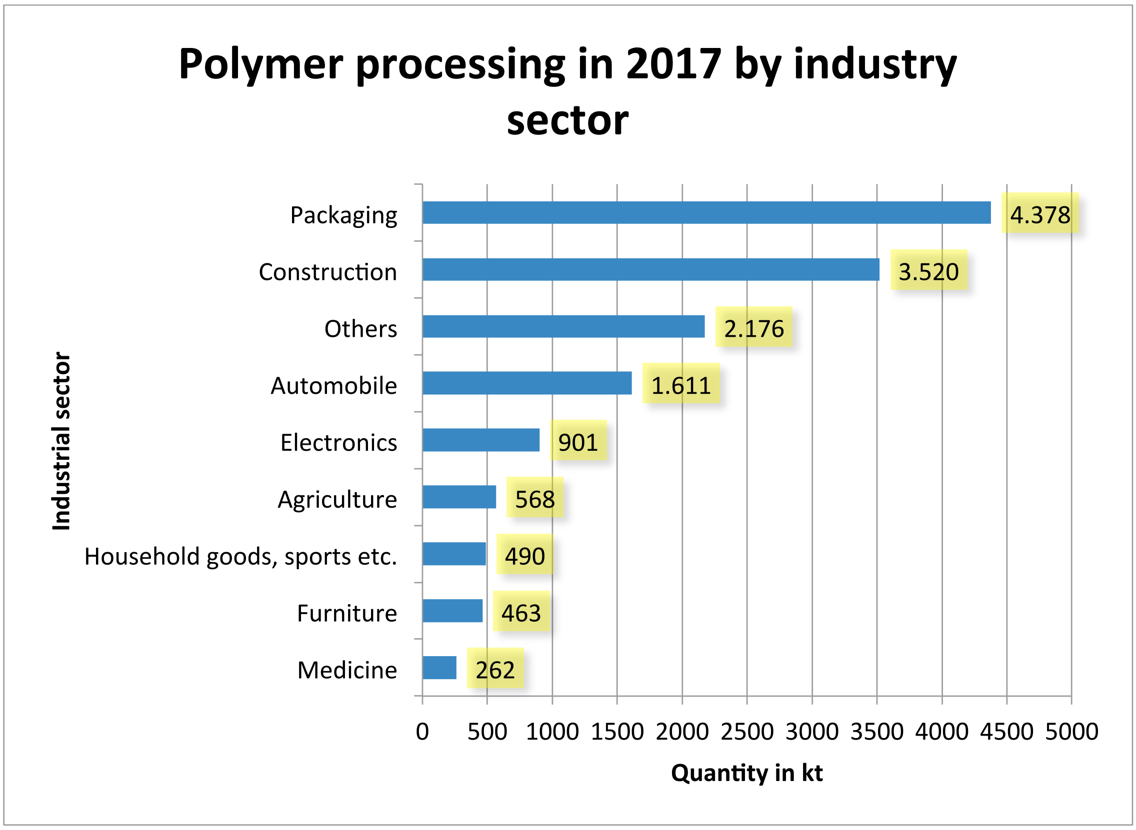

Figure 5: Polymer processing 2017 by industry sector; Source: [CMS18]

5.4 Market data by industry sector – total sales

As mentioned above the annual growth of the entire industry in 2017 was 4.8 % (table 4). Although 30 % of plastic is processed for packaging, the strongest performer in terms of sales is the construction sector with a share of 20.1 billion € and a growth rate of 5.2 %, followed by technical parts with a share of 18.8 billion € and consumer products (10 billion €) [GKV18].

Table 4: Sales by industry sector; Source: [GKV18]

	Sales volume in Billion €			Trend in %
Industrial sector	2015	2016	2017	2016-2017
Total	58.9	60,8	63,7	□ 4,8
Packaging	13,60	14,2	14,75	□ 3,9
Construction	18,3	19,1	20,1	□ 5,2
Technical parts	17,6	17,9	18,8	□ 5,0
Consumer products	9,4	9,6	10,05	□ 4,7

The current growth is driven by an increasing demand of plastic parts in the automotive, electrical and mechanical engineering sectors, the packaging industry, the household, consumer and medical goods sectors, and the booming construction sector.

5.5 Plastic waste and recycling rates

Between 2015 and 2017 the total plastic waste (including production and processing waste and also post-consumer waste) increased from 5.92 to 6.15 million tonnes, mainly driven by an increase in the post-consumer sector. Waste in the area of production and processing increased only slightly, despite a significant growth in production and processing volumes [CMS18].

Table 5: Postconsumer and total plastics waste 2015+2017; Source: [CMS18]

	Postconsumer waste		Total polymer waste	
Year	2015	2017	2015	2017
Recovery Rate	99%	99%	99%	99,4%
Energy recovery	61%	60%	53%	52%
Recycling rate	38%	39%	46%	47%
Mechanical recycling	37%	38%	45%	46%
Feedstock recycling	1%	1%	1%	1%

Disposal	1%	1%	1%	1%
Total waste quantity	5,00 Mio.t	5,20 Mio.t	5,92 Mio.t	6,15 Mio.t

In 2017 more than 99 % of plastic waste was recovered, with a slight upward trend of 0.4 % from 2015 to 2017. However, it is important to note that this initially high number is explained by the following facts: Recycling here does not indicate that the material has been indeed reused in some way, but that it was collected and provided for recycling (exports included. Material recycling in this statistical approach amounts to 46.7 %. Since there is a ban on landfill in Germany, only recycling and incineration are potential ways of plastic waste treatment, hence 99% coverage. Recovery is achieved by collecting systems like the dual system and take back schemes including deposit schemes e.g. for PET bottles, collection of residual waste, and the recycling of foils from the transport and industrial sectors.

The recycling rate of postconsumer waste, including mechanical and feedstock recycling, was about 39 %, of which the most recycled material were packaging [CMS18]. The essential basis for this is household-friendly packaging, the activities of the dual systems and the recycling of PET bottles. The remaining 61 % of the accruing waste was treated by energy recovery. From 2019, the new packaging law will come into force in Germany, which is to lead to recycling rates for plastics of 58.5 % by 2019 and 63% by 2022. Thus, a decrease of energy recovery can be expected. Moreover, the new plastics directive of the EU will lead to a change in measurement. In the future the material recycling rate in terms of real material reuse will have to be used. However, details on this are still unclear, e.g. the role of chemical recycling.

In total about 1,764 kt of recyclates were used in 2017, which is a share of 12.3 %. Significant quantities of recyclates were used especially in agriculture, construction and packaging applications. The recycled contents of these three segments were about 9 % for packaging, about 22 % in products for construction and about 35 % in agricultural applications [CMS18].

6. Regional distribution of the German plastics industry

As mentioned above, the German plastics industry is characterized by small and medium-sized companies, large corporate groups and corporations are the exception. The industry as a whole is characterized by networks and by close links between the plastic producers, the plastics processors and the plastics machinery industry.

As an umbrella organisation of the German plastic processors, the GKV (German Association of Plastics Converters) represents the economic and political interests of the industry. Its members, in total 829, are spread among the different sectors of the plastics converting industry (table 6).

Table 6: Membership structure of the GKV; Source: [AVK18], [FSK18], [IKI18], [PRO18], [TEC18]

Sector	Number of companies
Plastics Packaging	257
Reinforced Plastics	182
Technical Plastics Products	146
Foamed Plastics and Polyurethanes	132
Semi-finished and Consumer Plastics Products	112
Total number of companies	829

It can be assumed that the membership structure of the GKV is representative for the whole German plastic converting sector. Thus, the member data of the association were used to visualise the regional distribution of plastics processors. For this purpose, the membership list had to be revised according to the following points:

- Members producing technical plastic products (members of the sectorial association TecPart [146]) could not be included, because the association did not reveal their data
- Foreign member companies were excluded

After this revision, 674 relevant companies were initially identified, whereas approximately 85 % are manufacturers, the other 15% are recyclers, machine engineers and institutes. Figure 6 shows their spatial distribution all over Germany. Each flag marks one head office. It should be noted that overlaps of individual markings occur and not each flag is visible.

Figure 6: Map of Germany, flagged with plastic companies' location

This illustration shows the regional focus in the west and south of Germany. More specifically, agglomerations occur in the Rhine-Main area (1), North Rhine-Westphalia (2) and the western part of Lower Saxony (3). This region covers about 70 % of the plastic processors of the GKV.

Figure 7 shows a closer look to the "Ruhr area", an area in North Rhine-Westphalia (2) with a relatively high number of companies belonging to the plastics industry. Within a radius of 30 km 14 member companies / institutes (mainly plastic processors) of the GKV are located.

A, C, E, G, I, J, K, N = Processor
F, M,O = Retailer
B = Laboratory
M = Recycler

Figure 7: Map of the Ruhr area, showing companies of the plastic industry

7. Future perspective

At the beginning of 2018, the GKV asked its members how they forecast sales expectations and personnel planning. 60% of the companies surveyed expected a continuous growth and a positive overall result for the year 2018. Thus, 41% of the companies plan to increase their workforce [KUN18].

The statistic platform Statista provides a sales forecast for the sectors plastic packaging and construction elements (plates, foils, profiles and tubes) until the year 2020. For packaging, sales are expected to increase about 2.2%., from 15.1 billion € (2017) to 15.5 billion € (2020) [STA18a]. Sales are also expected to increase for construction, up to 6.2 % from 21.2 billion € (2017) to 22.5 billion € (2020) [STA18b]. The Statista data are purely based on mathematical models, which were determined on the basis of data, collected from 2009-2014 for packaging and 2010-2016 for construction.

Future perspective for a circular economy (EU-Strategy)

The way plastics are currently produced, used and disposed fails to capture the economic benefits of a more ‘circular’ approach and harms the environment.

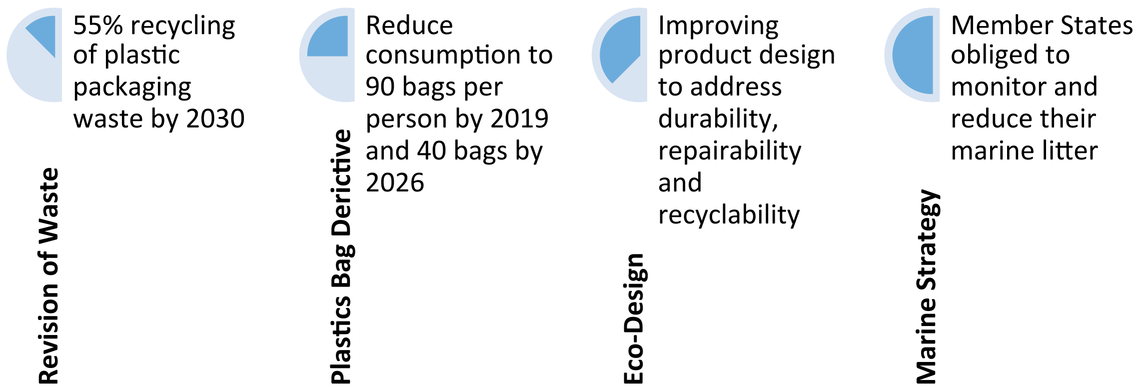

Figure 8: Factsheet on EU Plastics Strategy; Source: [EUR18]

Up to 13 million tons of plastic waste ends up in the world's oceans every year. The Plastic Strategy proposed by the European Commission demands for 2030, that all plastic packaging on the EU market will be recyclable; the consumption of disposable plastics is reduced and the intentional use of micro plastics lowers [EUR18]. This will also have a strong impact on the development of the German plastic processing industry.

Climate-KIC

References

[AVK18] AVK – Industrievereinigung Verstärkte Kunststoffe e.V., https://www.avk-tv.de/, 31.10.2018

[CMI14] Consultic Marketing & Industrieberatung GmbH, 2014, Produktion, Verarbeitung und Verwertung von Kunststoffen in Deutschland 2013- Kurzfassung -, Alzenau, http://www.tecpart.de/images/tecpart/Konjunktur/Consultic/endbericht_2013_23._sep_2014_kurzfassung.pdf, 21.11.2018

[CMI16] Consultic Marketing & Industrieberatung GmbH, 2016, Produktion, Verarbeitung und Verwertung von Kunststoffen in Deutschland 2015 - Kurzfassung -, Alzenau, https://www.bkv-gmbh.de/fileadmin/documents/Studien/Consultic_2015__23.09.2016__Kurzfassung.pdf , 21.11.2018

[CMS18] Conversio Market & Strategy GmbH, 2018, Kurzfassung Stoffstrombild Kunststoffe in Deutschland 2017, Mainaschaff, https://www.bvse.de/images/news/Kunststoff/2018/181011_Kurz fassung_Stoffstrombild_2017.pdf, 21.11.2018

[EUR18] European Commission, 2018, Turning today's challenges into opportunities - a European strategy for plastics in a circular economy, https://ec.europa.eu/commission/sites/beta-political/files/plastics-factsheet-challenges-opportunities_en.pdf, 21.11.2018

[FSK18] FSK-Fachverband Schaumkunststoffe und Polyurethane e.V., https://www.fsk-vsv.de/, 31.10.2018

[GKV18] GKV-Gesamtverband Kunststoffverarbeitende Industrie, http://www.gkv.de/de/statistik/, 21.11.2018

[IKI18] IK Industrievereinigung Kunststoffverpackungen e.V., https://www.kunststoffverpackungen.de/, 31.10.2018

[KUN18] Kunststoffxtra, https://www.kunststoffxtra.com/-1/de/news/gkv-meldet-erneut-rekordjahr-fur-2017-/5864/, 21.11.2018

[PRO18] pro-K Industrieverband Halbzeuge und Konsumprodukte aus Kunststoff e.V., http://www.pro-kunststoff.de/, 31.10.2018

[STA18a] Statista GmbH, https://de.statista.com/prognosen/400213/herstellung-von-verpackungen-aus-kunststoffen-in-deutschland---umsatzprognose, 21.11.2018a

[STA18b] Statista GmbH, https://de.statista.com/prognosen/313734/herstellung-von-kunststoffprodukten-umsatz-in-deutschland, 21.11.2018b

[TEC18] TecPart - Verband Technische Kunststoff-Produkte e.V., http://www.tecpart.de/index.php/en/, 31.10.2018

8. Overview of existing blockchain networks worldwide regarding recovery and recycling of plastics – Business Ideas & Models, Revenues and Blockchain Provider

As already mentioned, blockchain applications are seen as a beneficial lever for circular economy activities. In the global market, some blockchain applications already have been developed for the recovery and recycling industry. So what are the benefits of using these kinds of applications? What business models does blockchain create and where are revenue streams generated?

A study of the Wuppertal Institute has analysed 14 blockchain networks and applications for the recycling industry in the global market. The cases were identified by internet search and with guidance from experts. There are ten European, two American, one Australian and one Asian blockchain networks. These include Netherlands (3), Norway (2), Switzerland (2), Italy (1), Malta (1), United Kingdom (1), USA (1), Canada (1), Melbourne (1) and India (1). The networks have different geographical coverage, whereby nine are globally, one transnationally, three nationally and one regionally applied. The networks are in different development stages - six are in development phase, four are in running pilot projects, one is in early operational phase and two fully operational. There are different materials covered like plastic waste (4), different types of waste & end-of-life products including plastics (7), food products and their supply chain (1) and there is also one sharing platform for different types of products and services. Most of the blockchain networks use tokens and smart contracts, only cover end-of-life-treatment/Recycling and are based on the Ethereum platform.

The following table gives an overview about the existing networks and applications:

Table 7: Blockchain Networks and Application

1	Recreum	Switzerland
2	Plastic Bank (IBM)	USA
3	Agora Tech Lab	Switzerland
4	Empower	Norway
5	RecycleToCoin	United Kingdom
6	Cycled	Norway
7	Naturecoin	Canada

8	Troventum.bonus system	Malta
9	Foodchain	Italy
10	Circularise	Netherland
11	Excess Materials Exchange	Netherland
12	Project: European waste transportation on blockhchain	Netherland
13	ShareRing	Australia
14	Swachhcoin	India

8.1 Business Ideas

To understand how the blockchain applications work and where revenues are generated, it is useful to look at the different business models, which describe the structures and functions of the individual business ideas. However, the business ideas will be discussed first. There are two major starting point for starting the business ideas among the applications. First, material data is recorded early in the lifecycle on blockchain for closing of the cycle. Secondly, material data is recorded later in the lifecycle mostly to enable some sort of recycling or take back system, or stock taking. The first business idea is only used in the applications *Foodchain* and *Circularise*, whereby the second one is used in all other applications.

Basically, the two business ideas can be divided into further five business ideas that describe the different stages in more detail in which blockchain system could be used (see table 2).

Table 8: Business Ideas

	Business Idea	Blockchain Provider
1	Bonus Systems for Collectors	Recreum | Plastic Bank (IBM) | Agora Tech Lab | Empower | RecycleToCoin | Cycled | Swachhcoin | Naturecoin | Troventum
2	Full lifecycle documentation of products	Food Chain | Circularise | Excess Material Exchange
3	Streamlining and automating waste transportation	Project: European waste transportation on blockchain

4	Exchanging excess materials and products + matchmaking	Excess Material Exchange
5	Sharing products (private sector)	ShareRing

Most ideas evolved around collecting waste and receiving money or crypto currencies in return. These require the people to deliver material to collection points, whereby "*Cycled*" for example offers a pick up feature. "*Excess Material Exchange*" is a bit in-between as they provide a matchmaking service for materials and products where the data is put into the blockchain at either an earlier or later lifecycle stage.

8.2 Business Model Revenues: General Overview

There are seven possible revenue streams that can be generated:

1. Socially oriented concepts (e.g. Plastic Bank) ask for sponsors to buy or donate tokens.
2. The income generated through the collected materials might be higher than the value of the tokens/ the products/ services/ money that is passed on
3. IBM offers a "freemium" version – one either pay a smaller or larger fee with more options to them
4. Bonus system membership fees (Troventum)
5. Funding from Initial Coin Offering and Investments (e.g. NatureCoin)
6. Earning percentages of each traded Token (Swachhoin)
7. Selling the secondary raw materials, selling/renting out infrastructure sale (Cycled: smart bins), service fee charges to municipality waste collectors using the companies system (Cycled)

8.3 Inside the Business Models

1: Bonus Systems for Collectors

The goal of the business model is to increase the efficiency and volumes of waste collection (household waste) through bonus systems for collectors. The underlying blockchain system is Ethereum, that is used e.g. by **Troventum OS, NatureCoin, Swachhoin** and **Cycled**. These aim to significantly decrease the amount of non-recycled waste via increasing the efficiency and volumes of waste collection (through different bonus systems).

The objective is to lower the cost of production, increase the flow of sorted waste for recycling, optimize waste collection costs and secondary waste logistics, raise the volume and quality of secondary raw materials through recycling and lower raw materials production costs.

For example, in the **Troventum.bonus** system users receive points that can be exchanged for goods, discounts etc. **Naturecoin** is a reward system for recycling which works by deploying smart bins for recycling via large scale IT networks in cities. Consumers get a reward in terms of cryptocurrency for every recycled waste type and then exchange coins for goods/services provided by local vendors. **Swachhoin** is a system where domestic households receive rewards for proper waste management and can either sell these rewards or use them for various utility purposes offered by Swachhoin. When using **Cycled** as disposer receives tokens for handing over clean and sorted recyclables to the recycler at a current location that is equivalent to the quantity of recyclables. Collectors receive alerts and transport recyclables to nearest designated drop-off point. They also receive tokens equivalent to the distance travelled & quantity of recyclables collected.

As the blockchain applications follow different business models, the business cases are different as well. Troventum earns income through bonus system membership fees; Naturecoin receives funding from Initial Coin Offering and investments; Scwachhoin earns percentages of traded Tokens; the revenue of Cycled will be generated by the sale of secondary raw materials, sale of their smart bins. A service fee is charged as well to municipality waste collectors that use their system.

RecycleToCoin, **Empower** and **Agora Tech Lab** use tokens, QR codes and connected apps. In the case of **RecycleToCoin**, consumers recycle single-use plastic bottles and cans and receive a reward. Using the mobile app, alongside with physical machines and designated collection points, the system will allow the exchange of recyclable waste for BDC tokens. These tokens can either be exchanged for an eGift Card or donated to the main partner charity, the Plastic Bank. Charity Shops are able to express an interest in being involved, shops are paid to host the scheme's collection points.

Empower (Zafeplace blockchain platform) puts a value on plastic by incentivizing people to go and clean up plastic waste. Participants receive digital tokens called EMP with a fixed value (1 kg plastic waste = 1 EMP) that can be used for C2C or C2B trading, donated to enable more cleanup, or simply bought back by Empower for 1 USD per EMP. The EMP tokens are rewarded when private persons collect and deliver plastic waste to a certified plastic waste collector. The tokens are sponsored by individuals, businesses, organizations, businesses and governments. There is a monthly subscription fee that generates the revenue.

Agora Tech Lab has basically the same function. Citizens collect waste and receive tokens, whereby received tokens can be used for personal use, e.g. for personal governmental services. But tokens can also be pooled together, so communities can save for new neighbourhood services.

Plastic Bank is a special business model from IBM. It has the same concept as the blockchains already mentioned above. Private persons collect plastic waste and receive tokens for that, the tokens can be sent to others as well. It offers security, speed and access to goods and markets for people in developing areas. IBM offers its own blockchain platform to businesses and is in competition with Ethereum. The platform runs on IBM cloud and can be used for private purposes. Thus, IBM provides the server, the open source engine and the online platform to be used. There is a monthly subscription fee of 1000 USD for businesses and a 500 USD starter pack fee. Plastic Bank provides all-in-one service and access to blockchain. The system is 100% encrypted and it is a permissioned network, so the participants of the blockchain have known identities. This is relevant, as the blockchain needs to comply with the data protection regulation.

Recreum aims to motivate citizens to pre-sort waste instead of throwing everything away mixed with other waste types. Once a user throws away materials like glass, plastic, aluminium, used batteries, paper or wood into a dedicated place (whether it is a vending machine or a box for used batteries) the person can scan a QR code with the Recreum App (QR code screened by the machine). The user receives a specific amount of tokens that can be used to purchase supplies and services.

2: Full lifecycle documentation of products

Circularise and **Foodchain** use this type of method. This is done by blockchain technologies like the Ethereum platform, which tracks all product stages by covering all parts of the supply chain to create a "raw materials inventory". The Ethereum system uses tokens and smart contracts. The transmission of information collected across networks is powered by a method to consolidate transactions via tokens, for example Food-Tokens. Products have digital labels that can be displayed through QR codes, so that end consumers can track the supply chain and give feedback on products. The information database can also be used for better recycling processes. The company charges money for a small QR code on the product (Circularise) or gets money through selling tokens (Foodchain). In addition, Circularise for example promotes a communications protocol that allows communication in secure way, seemingly through smart contracts.

3: Streamlining and automating waste transportation

The Project "**European waste transportation on blockchain**" is launched on the public Ethereum network. The objective is to reduce supervision costs related to waste transportation between European countries.

4: Exchanging excess materials and products + matchmaking

This business idea considers materials like excess materials, components and products of any type. On the platform **Excess Material Exchange** all parts of end-of-life products that can be reused and recycled are covered. The platform is a digital facilitated marketplace where companies can exchange any excess material and products. The EME provides a reliable source for the buying and selling of secondary materials. By using this marketplace companies search time for sourcing secondary resources can be reduced by as much as 85%. At the moment waste processing costs represent on average 5% of the total revenue of companies. EME helps companies to turn their waste into wealth. By offering their materials, components and products on the marketplace companies will get paid for them instead of paying to get rid of it. EME could reduce a company's waste processing costs by as much as 150%. EME´s fuzzy matching tool connects available material streams with relevant data of thousands of scientific papers and patents. This allows EME to quickly identify alternative uses for each material. Eventually an AI toolkit will be developed to initially aid and ultimately automate the matchmaking between supply and demand, and between materials and their highest value reuse opportunity.

Companies will remain the owner of their own sensitive data while materials will be traced anonymously. The blockchain also ensures non-corruptibility and traceability of supply chains and will help prevent frauds. With a fully functioning EME the logistics will just be a click away. Until that time and during the pilot logistics EME will investigate how to optimise the logistics.

5: Sharing of Products (private sector)

The Business model aims to share products, vehicles and housing between private people.

SharePay for example, is the base currency that will allow users of the platform to pay for the use of third party assets. **ShareTokens** is a digital utility token that drives sharing transactions to be written to the **ShareRing** ledger that is managed by the ShareRing platform. Users get a standard account, whereby each account is represented by a 24-byte address. The account will contain 4 general fields: SharePay, ShareToken, Assets, Attribute. The Assets represent a tangible real-world or digital asset that is being shared, such as a car, a house, industrial machinery, an e-book, etc. The **ShareLedger** blockchain will feature highly customisable smart contracts. The company enables users to lease assets from a broad range of categories through a single smartphone app. For example, renting cars, trucks and trailers, sharing gardens, swapping books, co-housing, car sharing and social dining.

Most transactions, with the exception of exchanging SharePay to ShareToken between wallets on the ShareLedger blockchain, will incur a small transaction fee payable in ShareToken. This fee will reduce over time, inversely proportional to the current demand of ShareTokens.

9. Conclusion

The market analysis shows that while a variety of approaches exist, many of these only relate to the end-of-life to enable recycling. Only two cases identified address the whole lifecycle and can thus also be regarded as suitable for waste prevention of which recycling is not a part.

Moreover, it is interesting that most cases found are in a very early stage, either in build-up or development-phases. Only few are operational and only the Plastic Bank has gained size and maturity. Furthermore it is striking that many models are at least partly concerned with charity and social entrepreneurship and not with the realization of profit through their operations. For us this shows the general immaturity and uncertainty with blockchain applications.

None of the models directly regard regional applications as envisioned in this project. The analysis for the German market however shows that regions with a major agglomerations of plastic manufacturers exist and may be honed.

Concluding, the analysis show that there might be a potential for the Plastic waste recovery by regional blockchain networks envisioned here, but there is no direct role model to learn or chose from. Business model development will thus have to rely on innovative, self-created concepts.