THE FUTURE OF WASTE MANAGEMENT

TREND REPORT 2021

CDTM
CENTER FOR DIGITAL TECHNOLOGY AND MANAGEMENT

The Future of Waste Management

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The world is generating more and more waste. To solve and manage the global waste problem, we need functioning recycling facilities. STADLER is an experienced specialist in the field of turnkey, automated sorting systems for recyclable materials and high-performance components.

As a family business with a long tradition dating back to 1791, we take a long-term view on the global waste issue. This is why we are very proud of the collaboration with the CDTM, in which we jointly looked at trends and scenarios regarding the future of waste management.

Visit www.w-stadler.de for more information.

A project of the Center for Digital Technology and Management (CDTM)

The Center for Digital Technology and Management (CDTM) is a joint, interdisciplinary institution for education, research, and entrepreneurship of the Ludwig-Maximilians-Universität (LMU) and the Technische Universität München (TUM).

It offers the add-on study program „Technology Management" for students from various backgrounds, which provides students with tools and knowledge at the intersection of business and digital technologies.

The entire trend report was written by CDTM students under the close guidance of research assistants.

Visit www.cdtm.de for more information.

PREFACE OF THE EDITORS

As Herman Kahn, one of the founding fathers of modern scenario planning, nicely states, it is tremendously important for strategy and policymakers to get a deep understanding of possible future developments in order to be prepared for them.

The Center for Digital Technology and Management (CDTM) aims to connect, educate and empower the innovators of tomorrow. It is our mission to equip our students with the tools and knowledge they will need to become responsible leaders, who actively shape their future environment, rather than only react to changes.

This Trend Report is the result of the course Trend Seminar, which is part of the interdisciplinary add-on study program "Technology Management" at CDTM. About 25 selected students of various disciplines, such as Business Administration, Psychology, Architecture, Computer Science, Electrical Engineering, and others, work together on a relevant topic of our time. Over the course of seven intense weeks of full-time work during their semester break, the participating students dive deeply into the topic of the Trend Seminar. Working in several interdisciplinary sub-teams, students apply the knowledge of their main studies and learn new perspectives from their team members. They conduct trend research, develop scenarios of the future, generate ideas for innovative products or services, and detail them out into concrete business concepts.

> **"Everybody can learn from the past. Today it is important to learn from the future!"**
>
> Herman Kahn

We would like to take the chance to thank everyone who contributed and made this CDTM Trend Report possible:

We want to thank STADLER for supporting this Trend Seminar. Particularly, we want to thank Willi Stadler, Julia Stadler and Sebastian Küpper for their collaboration, their valuable insights, and their feedback throughout the whole project. We hope our findings support you in driving innovation in the context of Waste Management in the future!

In addition, we very much thank all our lecturers, who shared their knowledge and largely contributed to this project's success:

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Last but not least, we would like to thank the CDTM students of the class of Fall 2021. They put great energy and enthusiasm into this project, which made it a pleasure for us to supervise the course and coach the individual teams. Special thanks to the Heads of the layout -, editing -, and Q&A-team (Igor Rzhin, Florian Wiethof, Florian Kristof, Claudius Seitz) for finalizing the report.

Franz Xaver Waltenberger and Carla Pregel Hoderlein

Center for Digital Technology and Management (CDTM)

PREFACE OF THE PROJECT PARTNER

> **“ Be close to your employee, customer, and product.**
>
> Willi Stadler ”

The world generates ca. 2.0 billion tons of municipal solid waste annually, with more than a third of it not managed in an environmentally safe manner. Looking forward, global waste is expected to grow to 3.4 billion tons by 2050.

We need functioning recycling streams to solve and manage the global waste problem and reduce greenhouse gas emissions. Therefore, professional systems that sort recyclables according to material and color on a large scale are required to achieve the greatest possible yield and purity of these recyclables. STADLER has vast experience in the field of turnkey, highly automated waste sorting plants and high-performance key components. Our sorting systems and components operate in more than 50 countries worldwide.

But how can we further digitally enhance sorting and recycling facilities? How can digital technology create even more sustainable solutions for waste management? What are potential disruptive innovations? What could be potential new business models in that field?

As a family business with a long tradition dating back to 1791, we take a long-term view on the global waste issue and we would like to push the circular economy. We think waste management is essential, especially in times of climate change. We want to contribute to counteracting the constantly growing waste mountains all over the world. This is why we are very proud of the collaboration with the CDTM on trends and scenarios on the future of waste management.

The enclosed research findings from our collaboration with the Center for Digital Technology and Management (CDTM) confirmed our assumption at STADLER that waste management is a market with a lot of potential to make this world a more sustainable place to live. Thanks to the interdisciplinarity of the students, trends and potential business models were elaborated from a business, technology, and social perspective.

We would like to take the chance to thank everyone who has contributed to this great report. It was a pleasure to experience the hands-on mentality and agility of the CDTM students throughout the seven weeks of the project phase. We thank all the students of the CDTM cohort for their thorough analyses of trends, their fascinating presentations of the scenarios, and their inspiring business models for the future of waste management. We were deeply impressed by their team spirit and motivating energy. We especially would like to thank Franz Waltenberger and Carla Pregel Hoderlein for their perfect organization, ongoing encouragement, and continuous support.

Jürgen Berger, Dr. Bastian Küppers, Ulrich Sigmund, Julia Stadler and Willi Stadler
Stadler Group

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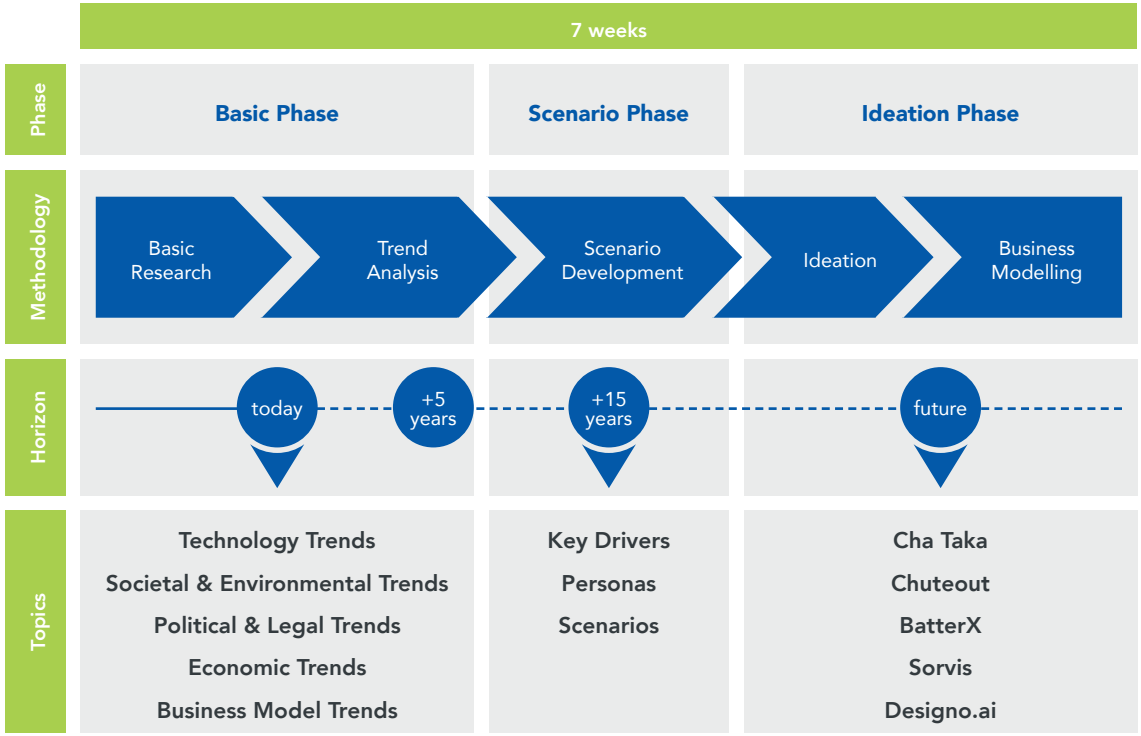
For a given topic that is highly impacted by digital technologies, the Trend Seminar pursues three main goals:

- To analyze the status quo and recent developments in order to identify important trends
- To develop extreme scenarios of the future in order to be prepared for upcoming challenges
- To develop future-proof product and service ideas and to detail them out into business concepts.

These goals are represented by the three phases of the trend seminar: the Basic Phase, the Scenario Phase, and the Ideation Phase.

Twenty-six students, supervised by two doctoral candidates, pursue the Trend Seminar in seven weeks of intensive full-time work alongside with their project partner. In each phase, interdisciplinary subteams are formed including students from technology, business, and various other backgrounds to combine versatile ways of thinking.



The **Basic Phase** yields a holistic overview on recent developments and trends in the environment of the overall topic. Based on the commonly used STEEP approach (Social-Technological-Economic-Ecological-Political), the status quo and trends in the fields society & environment, technology, economics, politics & legal, as well as emerging business models are analyzed. Knowledge is gathered by literature research, preceded by a series of input presentations by experts on the topic. The class is split into five teams, each working on one of the thematic scopes. At the end of the Basic Phase, the teams present their key findings to each other in order for everyone to get a holistic view on the topic to build upon in the following phases.

The **Scenario Phase** builds upon the analyzed trends in order to create four scenarios of different futures in twenty years ahead. Driving forces behind developments are identified and specified as drivers with bipolar outcomes. Once specified, all drivers are ranked according to their respective impact on the overall topic and the perceived degree of uncertainty regarding their outcome. Two key drivers that are independent from one another and have both a high impact and a high degree of uncertainty are chosen and, with their bipolar outcomes, used to create a scenario matrix of four scenarios. A timeline for each of the scenarios is created and the scenarios are sketched out using persona descriptions and visualizations. The Scenario Phase starts with a two-day workshop followed by group work in four teams. Teams are newly formed in order to include experts from each subtopic of the Basic Phase in each new Scenario Team.

In the third phase, the **Ideation Phase**, the goal is to develop innovative business concepts, which are then tested against the previously developed scenarios. Within a two-day workshop on structured ideation following the SIT approach (systematic inventive thinking), a large number of business ideas are developed. Out of these, the most promising five ideas are selected and further developed into detailed business concepts. The business model canvas by Alexander Osterwalder and Yves Pigneur serves as the base structure. At the end of the seminar, the business model concepts are presented to the project partner and guests.

LIST OF ABBREVIATIONS

3R
Reduce, Reuse, Recycle

AHK
Auslandshandelskammer

API
Application Programming Interface

B2B
Business to Business

CAD
Computer Aided Design

CAGR
Compound Annual Growth Rate

CAX
Computer Aided X

CCP
Container Control Programme

CDW
Construction and Demolition Waste

CE
Circular Economy

CEAP
Circular Economy Action Plan

CPG
Consumer Packaged Goods Market

CRM
Customer Relationship Management

CSR
Corporate Social Responsibility

DLE
Dendro Liquid Energy

DRS
Deposit-Refund Systems

DVR
Differential-Variable Rate

EEE
Electrical and Electronic Equipment

ELSA
End-of-Life Services by Astroscale

ELV
End-of-Life Vehicles

EPR
Extended Producer Responsibility

ERP
Enterprise Resource Planning

GACERE
Global Alliance on Circular Economy and Resource Efficiency

GDP
Gross Domestic Product

GHG
Greenhouse Gas

HICs
High-Income countries

i.e.
id est (this is)

ICT
Information and Communications Technology

IPO
Initial Public Offering

ISS
International Space Station

IT
Information Technology

JUWC
Joint Unit for Waste Crime

LEO
Low earth orbit

LMCIs
Low-and-middle-income countries

MSW
Municipal Solid Waste

MVG
Münchner Verkehrsgesellschaft

MVP
Minimum Viable Product

OECD
Organisation for Economic Co-operation and Development

OEM
Original Equipment Manufacturer

PET
Polyethylene Terephthalate

PRO
Producer Responsibility Organization

QR
Quick Response

RaaS
Recycling-as-a-Service

REE
Rare Earth Elements

RFID
Radio-Frequency Identification

SaaS
Software as a Service

SDG
Sustainable Development Goal

SEO
Search Engine Optimization

SME
Small and Medium Enterprise

SSE
Small Scale Entrepreneur

STEM
Science, Technology, Engineering, Mathematics

UI/UX
User Interface/ User Experience

UN
United Nations

UNODC
United Nations Office on Drugs and Crime

VC
Venture Capital

WEEE
Waste from Electrical and Electronic Equipment

WMS
Waste Management Services

WtE
Waste-to-Energy

XRT
X-Ray Transmissiosn

TRENDS

The following chapter lists current trends that have a strong impact on the future of waste management. In accordance with the Basic Phase methodology, trends and related driving forces are structured into five areas: technological trends, societal and environmental trends, legal and political trends, economic trends, and business model trends.

TECHNOLOGY TRENDS

INFLUENCING THE FUTURE OF WASTE MANAGEMENT

Digitalization of Supply Chains
Rapid Product Release Cycles
Waste-to-Energy
Chemical Recycling
Space Debris

TECHNOLOGY TRENDS

Influencing the Future of Waste Management

New technologies shape the future of waste management in many forms and at various stages, from tracking waste generation to new ways of transforming waste into value. One of the key drivers of technology adoption in waste management is the global shift towards a circular economy: Preventing waste and keeping materials in use by recycling. As global waste generation as well as the level of urbanization are both rising, the 3R (Reduce, Reuse, Recycle) goals are becoming ever more crucial for governments and waste management firms and can only be achieved with the help of new technologies.

Currently, the processes in waste management lack transparency and efficiency, and this is where digital technologies come into play. Building smart infrastructure for waste collection, utilizing for example smart bins or radio-frequency identification (RFID) tags, enables waste management companies to track waste supply chains. By doing this, they can identify waste generation patterns and optimize waste collection routes. Data-driven approaches in sorting, such as AI-empowered waste classification can increase the efficiency of waste processing and the share of recyclables.

However, not only waste management is affected by digitalization. Many businesses embrace their digital transformation to stay competitive, reduce costs and increase revenues [1]. One of the biggest disruptions in the current digital era is the acceleration of product release cycles. In recent years, the average product development cycle was reduced from 48 to 25 months [2]. While this tendency satisfies a growing consumer individualism, it poses a huge challenge for waste management. From fast fashion to e-waste (WEEE), rapid product cycles result in more waste being produced.

The landscape of domestic solid waste is changing as well. By 2035, there will be around 142m tons of residual waste that will need to be handled [3]. Waste-to-energy (WtE) technologies use waste for generating renewable energy, thus reducing the amount of recoverable waste being landfilled and contributing to the circular economy goals. As WtE is being advanced by emerging technologies, e.g., direct conversion to derivative biofuels, it creates an increasing number of opportunities to recover energy.

Apart from transforming waste into energy, emerging technologies are making it possible to convert waste into valuable materials. Plastic recycling is one of the most problematic areas of waste management, as many plastic materials are either not recyclable or downcycled, id est (i.e.), converted to lower quality items [4]. By turning waste back into its base chemicals, chemical recycling allows to avoid downcycling and has the potential to dramatically improve recycling rates.

Last but not least, technological development enables humanity to fulfil its ambitious goals to explore and make use of space. From low earth orbit (LEO) satellites to space tourism, governments and commercial companies step up in the race for space superiority. This competition inevitably extends the problem of waste management into space: From 2000 to 2021, the number of space debris parts larger than 10cm has risen by 290% [5]. Removing existing and emerging space debris represents a crucial technological challenge for future waste management.

DIGITALIZATION OF SUPPLY CHAINS

Data-driven Approaches Increase Transparency and Efficiency of Waste Management

The lack of transparency and automation, the growing com plexity of tasks and the involvement of different stakeholders lead to inefficiencies in waste management and, as a result, to a significant loss of resources [6], [7]. The shift towards a circular economy (CE) requires the deployment of digital technologies enabling data-driven approaches for more transparent and effective waste management at all stages [8]. Especially at the waste collection stage, which currently accounts for 70% of the operational cost in waste treatment [9], connectivity technologies (such as IoT for smart bins [10] or RFID tags [11]) can create valuable data. Such data enables waste management firms to understand and react to waste generation patterns and increase the efficiency of waste collection via route optimization [12]. Data-driven approaches can also significantly optimize and improve the efficiency of waste sorting processes [46]. Machine Learning techniques and artificial-intelligence (AI) empowered robotics for waste recognition and sorting represent a crucial step in the circular economy transformation [13].

Facts:

- The employment of more than 400 smart bins in Cascais, Portugal enabled the city to reduce operational costs for waste collection by 40% and energy costs by 20% [15].
- Already existing AI-powered sorting machines can handle up to 160 recyclables per minute, in comparison to 30-40 items by humans [16].
- The Austrian AI-Waste project combines waste images with the data of sorting plants to identify the type and composition of the processed waste. This technology is expected to increase the recycling share of recycled materials by at least 10% [17].

Key Drivers:

- Significant improvements in connectivity technologies such as 5G enable cities to deploy smart waste infrastructures [18], [19].
- Increasing complexity in operations due to the growing amount of data and cost pressure push waste management companies to increase efficiency. It can be achieved via digital technologies ranging from digitally advanced operations to AI-empowered sorting [20], [8].
- Many policies, such as the European Commission (2020) circular economy action plan (CEAP), require the adoption of digital technologies in waste management, especially for tracking and monitoring of wastes [21], [8].
- Due to established tracking technologies, customers have got used to having real-time data on their orders [8].

Challenges:

- Waste management firms in Germany see data protection as a key barrier to the digitalization of their processes, as they may become targets of offensive information technology (IT) warfare [20], [8].
- Digital innovation requires high investment costs from waste management firms and does not pay off immediately [20], [8].
- Generating reliable digital entities for waste tracking can be challenging, e.g., quick response (QR) codes or RFID tags cannot be read if waste is damaged [21].

Impact on Waste Management:

From an environmental perspective, digitalization and optimization of waste management processes reduce the amount of waste ending up in landfills and increase the recovery rate of recyclables [22]. Moreover, tracking technologies and data analytics in waste management create transparency for stakeholders and help to better understand the patterns of waste generation and facilitate policy regulations [8], [12]. Making the data available to the public may also incentivize greener behavior and the "know-before-you-throw" pattern among citizens [8], [12]. Digitalization of supply chains has a broad and rather positive impact on waste management, enabling the circular economy goals.

RAPID PRODUCT RELEASE CYCLES

Technological Progress Leads to Artificial Obsolescence, Creating More Waste

Originating from the principles of agile software development, used by companies like Mozilla and Google [53], rapid release cycles are becoming tremendously popular. Frequent product updates and iterations make the principle attractive for application in product portfolios [52]. Shorter product release cycles are reducing the average product lifecycle spans, leading to faster disposal of products [72]. Generally, a rapid product release cycle covers all steps of the product development cycle ranging from the ideation over the prototyping to the final release of the product [54]. E.g., Volkswagen managed to shorten the product release cycles of the Volkswagen Golf to four years, having started with a release cycle of nine years in 1974 [65], [72], [51]. The acceleration of product release cycles is mainly enabled by new technologies such as simulation and production automatization [72]. In addition, users push the product release cycles by demanding for the latest technological product series [73]. Faster product release cycles combined with a decrease in product lifetime due to consumerism seem to create new challenges in managing the resulting waste [55].

Facts:

- Average product lifetime has been cut by 50% due to new manufacturing methods [72], such as computer aided design (CAD), computer aided X (CAX) or three-dimensional (3D) printing [66], resulting in shorter product release cycles [68].
- Shorter product life cycles are increasing the amount of waste, e.g., fast fashion waste grows 40% yearly as release cycles in the fashion industry fell from 61 to two weeks over the past decade [61], [63].
- Driving faster product development, the market for rapid prototyping is currently rising with a compound annual growth rate (CAGR) of 31% [56].
- Across all industries, 50% of the annual revenue is created by products that have been released less than three years ago indicating a decline of long-term "cash cows" in product portfolios [64].
- The market for robotics that speeds up manufacturing and rapid product release cycles is expected to grow by 175% by 2030 [62].

Key Drivers:

- Albeit Moore's law is not applicable these days anymore, the fast releases of more powerful devices are triggering the customer's needs for new devices even though the improvements are not significant [74].
- Customer demand for individualization and user-centric design as well as fast manufacturing is driven by advancements in cloud manufacturing (interconnected peers in the manufacturing and production chain) and AI [58], having an expected CAGR of approximately 20% until 2025 [59].
- Significant improvements in digital prototyping are reducing time to market as well as lowering costs for manufacturing and product creation [69].

Challenges:

- E-waste caused by the rapid technology cycles [60] is very hard to manage as new manufacturing technologies allow the manufacturing of even smaller components which makes the separation of the used materials even more challenging [75], [76].
- Affected by the short development and manufacturing cycles, products often lack the connection of functionality and end-of-life management, which hinders the disassembly of the products for recycling [77].

Impact on Waste Management:

The number of product disposals due to rapid product release cycles will keep on rising, especially in areas like consumer electronics and fashion [70], [71]. Waste management is thereby affected in two ways: New manufacturing technologies like layer-based manufacturing block effective component disassembly with material separation becoming more complex. Overall, the acceleration of product release cycles triggers shorter product life cycles resulting in an increasing amount of waste. To handle the rising and more complex amount of waste new technologies and business models will emerge in the coming years.

WASTE-TO-ENERGY

Leverage Technology to Turn Waste into Energy

WtE technologies process waste into energy, e.g., in the form of electricity, heat or transport fuels [50]. Beyond pervasive WtE technologies, recent technological advances usher the rethinking of waste recovery and therefore provide significant opportunities for market players. The growing world population, rising urbanization and economic growth are changing the landscape of waste in terms of generation rates and waste treatment [51]. Thus, waste management faces the challenge of increased domestic solid waste as well as the fulfillment of stricter government regulations for achieving a circular economy [52]. WtE technology contributes to tackle these challenges. By using waste as a precious resource for generating renewable energy, WtE contributes to a renewable future energy mix while reducing landfilling. In more detail, WtE is advanced by emerging technologies, e.g., direct conversion to derivative biofuels, a biochemical WtE technology that converts diverse feedstocks such as municipal solid waste (MSW) into biofuels and valuable co-products within a single process step [53]. These technologies create opportunities by leveraging the circular economy in the form of efficient renewable energy generation.

Facts:

- In the EU, the quantity of MSW incinerated rose from 32mn tons in 1995 to 70mn tons in 2018. From the EU's current WtE incineration capacity of 101mn tons, a potential of 248 new WtE plants in the European Union (EU) can be derived [3], [55].
- WtE accounts for 4.3% of Germany's primary energy use [56].
- The WtE and Biomass sector has experienced significant growth in investment for Europe in 2019, rising 12% to 3.1bn US dollars (USD) [57].

Key Drivers:

- The EU adopted the CEAP in 2020. The package introduces new waste management targets including reducing the landfilling of MSW to 10%. To successfully close the loop, WtE waste treatment is essential where recycling is not appropriate or yet feasible [58].
- The EU's 2030 targets for greenhouse gas (GHG) emissions are a reduction of 40% compared to 1990 levels. Additionally, the goal of reaching a 32% share of renewable energy by 2030 will make climate-friendly WtE investments more attractive [59].
- Emerging WtE technologies, such as Dendro Liquid Energy (DLE) are expected to create significant opportunities for the market players, providing the benefits of four times higher efficiency in terms of electricity generation and no emission discharge [51].

Challenges:

- High operating costs and the ceased governmental funding for incineration technologies make the production of energy from MSW economically challenging [51].
- Incineration is still considered as a WtE technology with a higher negative impact on the environment than for instance common recycling technologies. This impact has to be reduced by further development and implementation of alternative WtE technologies and emission control strategies [53].

Impact on Waste Management:

The increasing use of WtE is crucial to managing the projected future waste amount with a sustainable positive impact, emphasizing WtE as an enabler of the circular economy. The development of emerging WtE technologies leads to increasingly efficient and environmentally friendly energy recovery from waste. It generates valuable by-products and maximizes the impact on the circular economy and the contribution to a renewable energy supply.

CHEMICAL RECYCLING

Turning Plastic back into its Base Chemicals to Create New Polymers

Current technologies for recycling plastics are not able to support a fully circular economy. Incineration turns waste into energy, thus removing material from the cycle while also being highly polluting the environment [60]. Mechanical recycling cannot efficiently handle a mix of different materials, making complex sorting necessary [61]. Even then, most mechanically recycled plastics are of significantly lower quality [62], [63], [64]. By turning mixed plastic waste back into base chemicals to produce new polymers, chemical recycling has the potential to dramatically improve recycling rates and reduce plastic waste in landfills or incineration [65]. Complex sorting and downcycling can be avoided [66].
Companies like Badische Anilin- und Soda Fabrik (BASF) are investing in chemical recycling driven by its promising economic benefits and the increasing demand for sustainability transparency of the industry by politics and society [65], [62], [63], [66].
Combinations of chemical and more traditional recycling methods have the potential to reshape the entire plastics industry, including waste management, towards an entirely circular economy [63].

Facts:

- Since 2018, BASF, Nestle, Biofabrik, and Shell have been testing chemical recycling on pilot volumes of plastics. Since 2020, they have been investing in the first commercial plants scalable to a capacity of several hundred tons per day [65], [67].
- PlasticsEurope has announced a significant increase in their investment in chemical recycling from 2.6bn EUR in 2025 to 7.2bn EUR in 2030 [71].
- Ideal chemical upcycling avoids up to 4.2 kg carbon dioxide (CO2) and 1.4 kg oil per 1 kg of treated polyethylene terephthalate (PET) waste [66].

Key Drivers:

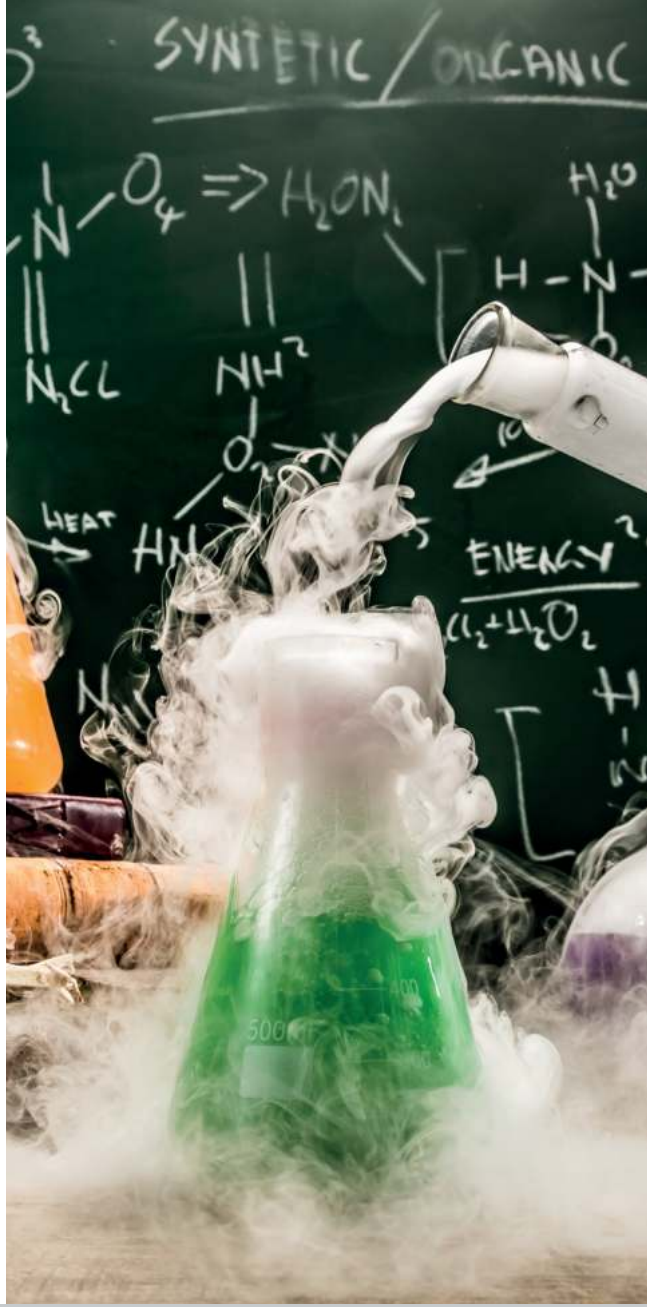
- Societal pressure against the plastic industry is increasing. The public opinion on companies is heavily influenced by their environmental image, e. g. how they are dealing with plastic pollution [62].
- Sustainability reports become a major indicator of a company's environmental image. Thus, the demand for recycled, high-quality plastics by the industry is increasing [68], [66]. If more plastics are chemically recycled, investment needs for plastics production and total industrial carbon emissions are decreased [62].
- Reusing and recycling plastics are becoming a more and more attractive business for the petrochemicals and plastics sector [62].

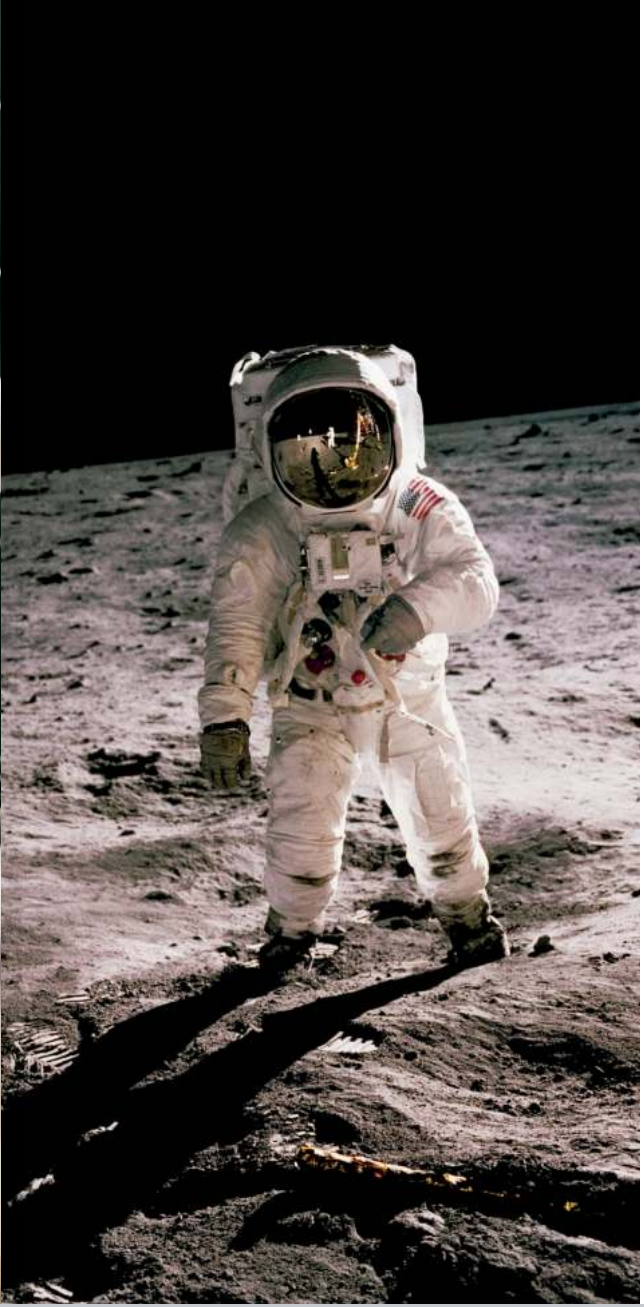
Challenges:

- Chemical recycling technologies are still immature [63]. Most of the technologies are still at laboratory and pilot-plant scales [65].
- There is limited evidence that the different chemical recycling technologies will be competitive at the industrial level under current market conditions [68].
- It is hard for chemical recycling to be a viable and scalable solution in the short run for the plastic problem due to its high energy demand and research costs [69].
- There is no EU-wide vision of a holistic recycling system that incorporates chemical alongside mechanical recycling [68].

Impact on Waste Management:

Chemical recycling will create value in previously unrecyclable plastic waste. Thus, a higher volume of waste must be managed by the waste management organizations [65]. Also, current mechanical recycling will be combined with chemical recycling technologies to maximize recycling effectiveness [63]. This will immediately lead to a redirection of plastic waste from landfills or incineration to plastics production [70]. The need to sort different plastics for recycling would decrease, as most plastics are processed to the same or similar base materials [70]. Chemical upcycling to value-added products will increase the demand for recycled products and might turn the traditional recycling industry into the main industrial plastics supplier [66].





SPACE DEBRIS

Will Increasing Space Waste Make the Orbit Unusable?

Space debris describes man-made objects in space not serving a useful purpose anymore. Common examples for space debris include non-functional satellites, abandoned launch vehicle stages or solid fuel containers of rockets [72]. Mankind's expansion into space by e.g., commercializing space flights or launching ever more satellites [73], increases the amount of waste in space, too [74].
At a traveling speed of 28,000 km/h, space debris can critically damage any satellite, space station, or astronaut it collides with [72]. To make things worse, as the amount of space debris increases so does the risk of collision. [74]. The worst-case scenario is known as the Kessler syndrome: Too much space debris kicks off a vicious cycle where more and more objects crash. This creates even more space debris, thus further increasing the risk of additional collisions [72]. LEO could become effectively unusable, resulting in a breakdown of telecommunication networks or Global Positioning System (GPS) navigation systems that rely on LEO satellites [75]. Given the intensifying problem of space debris, first efforts to commercialize orbit cleanup in the coming years have been proposed e.g., by Astroscale [76].

Facts:

- From 2000 to 2021 the number of space debris parts larger than 10cm has risen by 290% from roughly 7,500 [77] to 29,200 [78].
- In 2020 alone, the International Space Station (ISS) had to engage in 3 debris avoidance maneuvers i.e., moving the space station to prevent collision with highly damaging space debris. This is double the average yearly number of maneuvers of 1.5 [74], emphasizing that "Debris is getting worse!" to quote Jim Bridenstine, former head of the National Aeronautics and Space Administration (NASA) [79].
- Last year, 1283 satellites were launched into space, the highest number ever recorded. 2021 is on track to handily surpass 2020 in number of launched satellites [80].

Key Drivers:

- 3.7bn people could gain access to the internet [81] through LEO satellites. This drives private space companies to launch an estimated number of 50,000 satellites over the next few years. The left-over fuel tanks of some rockets launching these satellites [82] as well as the satellites themselves will make the orbit more crowded. This increases the risks of collision and amount of space waste [75].
- Moreover, many rocket launches by private companies like SpaceX, leaving fuel tanks as space debris, are driven by their founders' ambitions to e.g., colonize new planets [83].

Challenges:

- Removing existing space debris presents a key challenge: First, it is technologically challenging to develop a cleaning vehicle such as Astroscale's ELSA-d system, which uses magnet technology to capture and push space debris into earth's atmosphere where it burns. Second, the business case for this costly endeavor remains unclear. Third, the regulations are complex and incomplete [84].
- Designing future launches to minimize the generation of new space debris will be technologically challenging, yet crucial [85]. Around 90% of rocket remainders meet debris mitigation measures nowadays. However, only 50% of satellites who don't naturally burn in the atmosphere meet said measures [86].

Impact on Waste Management:

Space debris will extend waste management to space. This will require groundbreaking technological waste management solutions [72].
Currently, space law, guided by the UN, holds states liable for damage caused by objects launched from their countries, regardless of whether the objects were launched by a government or private entity. Changing this liability regime will incentivize and involve private space companies in the waste management process [87].
Space debris will drag orbital waste management into the geopolitical arena. Given that any space debris cleaner could be used as an anti-satellite weapon, diplomats and military officials will be watching the space waste management industry closely [85].

SOCIETAL & ENVIRONMENTAL TRENDS

INFLUENCING THE FUTURE OF WASTE MANAGEMENT

Growing Population & Income
Rapid Urbanization
Sustainability is Trending
Demand for Convenience
Increase in Resource Productivity

Florian Kristof, Philipp Zinnenlauf, Igor Rzhin, Annabell Maria Schaefer, Paulina Westerman

SOCIETAL & ENVIRONMENTAL TRENDS

Influencing the Future of Waste Management

Every day individuals, corporations, and governments make decisions about consumption and waste disposal, which have a direct impact on an area's health, productivity, and cleanliness. Additionally, many societies are confronted with accumulated waste from decades of economic growth, a cross-generational problem that requires urgent action. Especially for low-income countries, effective waste management remains a challenge as it presents the single highest budget item for many local administrations. Environmental outcomes and their economic implications are also inextricably linked to waste management. If waste is poorly managed, it negatively affects the environment as well as public health and hinders economic development.

There are a variety of social and environmental trends, of which the six most influential ones are elaborated in detail:

First, the world waste mass is increasing as the total population size is projected to grow until the end of the century. This growth is largely driven by low-income countries, which at the same time are projected to experience economic upwind. As waste production correlates with income levels, a resulting increase in material consumption will result in increased global waste production.

Additionally, an estimated urban population increase by 2.5bn people until 2050 significantly challenges public administrations. Uncontrolled urbanization, especially in developing countries, complicates the provision of the most basic services such as waste management. Since mismanaged waste pollutes the environment and thus endangers human health, efficient and sustainable waste management is a core layer of urban life quality.

Furthermore, there is a growing interest in sustainable behavior among consumers, companies, and governments. Various global movements, public education as well as pressure from close family members, friends, and social groups are driving this trend. Despite the rise of a to-go and convenience culture, companies start to design and manufacture sustainable products. As a result of this development, the increasing waste generation may slow down in the long run.

Furthermore, the personal need for a convenient consumption experience is strongly increasing and among the most important factors when making a purchase decision. Busy lifestyles and the current on-demand culture drive the amount of waste generated and create the need for convenience up to disposal. This requires waste management to address convenience along the entire value chain.

In addition, a global waste recycling rate of only 15% reveals the degree of ecosystem contamination and the interrelated risk for public health. Unmanaged or mismanaged waste, especially in the form of plastics and WEEE, releases hazardous materials in the environment and thereby endangers biodiversity, contaminates food chains, and ultimately threatens human health. An increasing population and income growth reinforce the need for environmentally sound waste management methods.

Lastly, as the demand for natural resources increases, governments are forced to increase resource productivity by applying the 3R principle and adopting principles of CE.. Waste management stakeholders overtake a crucial part in increasing recycling rates and the quality of recycled material.

GROWING POPULATION & INCOME

A Growing Population and Economic Developments Will Increase the World Waste Mass

In the future, our world's demographic structure will be undergoing changes that will fundamentally affect the way we will have to manage waste. On the one hand, global population growth is slowing down and will come to a halt by the end of the century [88]. On the other hand, the populations in many low- and middle-income countries (LMICs) are continuing to grow rapidly [89]. Just nine countries will account for half the global population growth in the coming decades, eight of them are LMICs. The rise in income levels and the development of the economy in LMICs are also noteworthy developments. As a country grows and prospers, it offers more products and services to its citizens [90]. Therefore, average consumption per person increases, leading to a corresponding increase in waste [91]. While high-income countries (HICs) have contributed to the growing waste mass for decades, LMICs are merely catching up to HICs' consumption levels.

Facts:

- The total population size is projected to grow by about 23.8% to 9bn by 2050 [88]. Half of this growth is expected to be concentrated in LMICs [89].
- Life expectancy increased globally by 7.5 years within the last 20 years [93].
- The Gross Domestic Product (GDP) per capita in LMICs rose by 325% since 2000 to 5.012 USD. In comparison, global GDP rose by 107% to 11.417 USD since 2000 [100].
- HICs currently generate 34% of the global waste, while LMICs generate only about 5% [91].

Key Drivers:

- Increased life expectancy and continued high fertility, especially in many LMICs result in a growing world population until the end of the century [89].
- A development known as demographic transition, which describes the asynchronous timing of first a decline in mortality that starts the population growth and then a decline in fertility which brings the population growth to an end [81].
- There is a positive correlation between waste generation and income level, even though this correlation reaches a plateau in HICs [91]. Rising income levels in LMICs result in increased material consumption which is leading to a higher per capita waste production.

Challenges:

- Pandemics are expected to increase in frequency and severity [97] resulting in a potentially declining life expectancy [98].
- As a result of the COVID-19 pandemic, there is a global economic contraction of 7%, with LMICs most affected [92]. This means that global consumption could also decrease due to less available money for consumption.
- Innovations to establish better resource efficiency and circularity strategies could reduce the world waste mass regardless of population growth [99].
- Growing consumer awareness about recycling [136] and demand for more sustainable products [124] could reduce waste mass.

Impact on the Future of Waste Management:

Global consumption levels rise due to the increasing world population size and rising income levels, particularly in LMICs. To deal with the growing mass of waste, governments must devise more sophisticated disposal methods. While the COVID-19 pandemic may temporarily slow the global economy, it is not likely to halt the global waste problem. In spite of waste management being a global concern, not all countries were so far able to manage it in the same manner due to economic or infrastructural limitations. Waste management could benefit from this trend in the future as the waste mass continues growing in LMICs, while economic development and growing populations are driving government prioritized infrastructure investments.

SUSTAIN-ABILITY IS TRENDING

Sustainability is Increasingly Important to Consumers, Companies, and the Government

Sustainable intentions influence the decisions of a constantly growing number of consumers, companies, and governments. Movements like "Zero-Waste" or "Fridays For Future" rethink consumerism and push for change towards more sustainable behavior. An increasing number of consumers choose products that are produced from non-scarce resources, are eco-friendly, and fit their values [124], [125]. As a result, they choose products based on their environmental impact and their level of social sustainability. These consumption habits span across new and second-hand products [126]. At the same time, concepts to prevent food waste appear globally and start to gain popularity [127] ,[143]. The majority of people even state that the eco-friendly behavior of companies has become more important to them [128]. Companies aiming to enhance their market share by offering sustainable products combined with substantially increasing funding opportunities for sustainability-focused startups drive the magnitude of this trend [129], [130].

Facts:

- In 2019, 47% of internet users worldwide said that they switched products or services due to brands incompatible with their personal values. Environmental concern depicts the main reasons why consumers switched [124].
- In 2019 sustainably-marketed products represented only 16% of the total consumer packaged goods market (CPG). Nevertheless, this segment grew 5.6 times faster than the traditional CPG market, accounting for 54.7% of the total CPG market growth [129].
- Funding opportunities for sustainable startups are increasing substantially: 7.4bn EUR have been invested by venture capital (VC) into startups fostering sustainability with technological solutions in the first half of 2021, compared to 4.7bn EUR in 2020 [130], [131], [144].

Key Drivers:

- Global movements turn the political and social gaze towards climate change and pollution. For instance, "Fridays For Future" at times mobilized over 500,000 people [133].
- Immediate surroundings have the strongest impact on the personal interest in sustainability [134]. Here, social pressure arises due to the fact that consumers prefer to do the "right thing" as perceived by family, friends, neighbors, and social groups. [135].
- Education leads to a greater awareness of consumption and therefore to a more sustainable behavior [136].

Challenges:

- The "to-go" culture develops simultaneously to sustainability trends [137], leading to more packaging waste.
- For customer satisfaction, convenience is more important than social responsibility or charitability [138].
- The readily available exposure to sustainability limits the active cognitive involvement in consumption behavior resulting in consumers thinking that buying sustainably labeled products is enough to address the problem without considering the importance of proper disposal [139].
- Greenwashing tricks customers into buying pseudo-sustainable products. In addition to damaging a business' reputation, incorrect beliefs about recyclability may lead to more waste [140], [141], [142].

Impact on the Future of Waste Management:

Influence by global movements, one's immediate surroundings, and the political landscape lead to more sustainable consumption habits. Consumers increasingly buy products that are eco-friendly and fit their values. Typically, these products use less packaging or one that can be recycled. Companies are driven towards truly sustainable products by prevalent market potentials, regulations, and the potentially harsh backlash if greenwashing is revealed [140]. These changes result in a decrease in waste generation and a greater level of waste recycling. In spite of this, convenience demands such as "to-go" options still create unnecessary waste [137].

RAPID URBANIZATION

An Increasing Urban Population Reveals Waste Management as a Key Lever for Urban Life Quality

The ability of governments to successfully handle 2.5bn additional people in cities until 2050 will determine the extent to which cities of the future will be safe, resilient, and sustainable [101], [102]. The interlinkage of urbanization and economic development has the potential to foster economic opportunities and increase living standards [123]. Thus, efficient planning and management of urban areas enables cities to evolve as accelerators of social progress and shared prosperity [102]. However, uncontrolled rapid urbanization imposes acute challenges on local and national governments: Inefficient urban governance can accelerate social inequality, exclusion, and environmental pollution [103], [104].

Facts:

- 56% of the population lived in urban areas in 2020, an increase by 10 percentage points compared to 2000 [106], [121].
- 93% of urbanization will occur in developing countries and 40% of global urban expansion takes place in informal settlements [108], [109].
- Cities are powerhouses of the global economy, generating more than 80% of global GDP. At the same time, cities depict a major contributor to climate change by producing more than 60% of global GHG emissions [110], [111].
- In developing countries, MSW generation per capita in urban areas exceeds the one in rural areas: In Vietnam, MSW generation per capita is two times higher in urban than in rural areas (0.7 vs. 0.3 kg per day) [107].

Key Drivers:

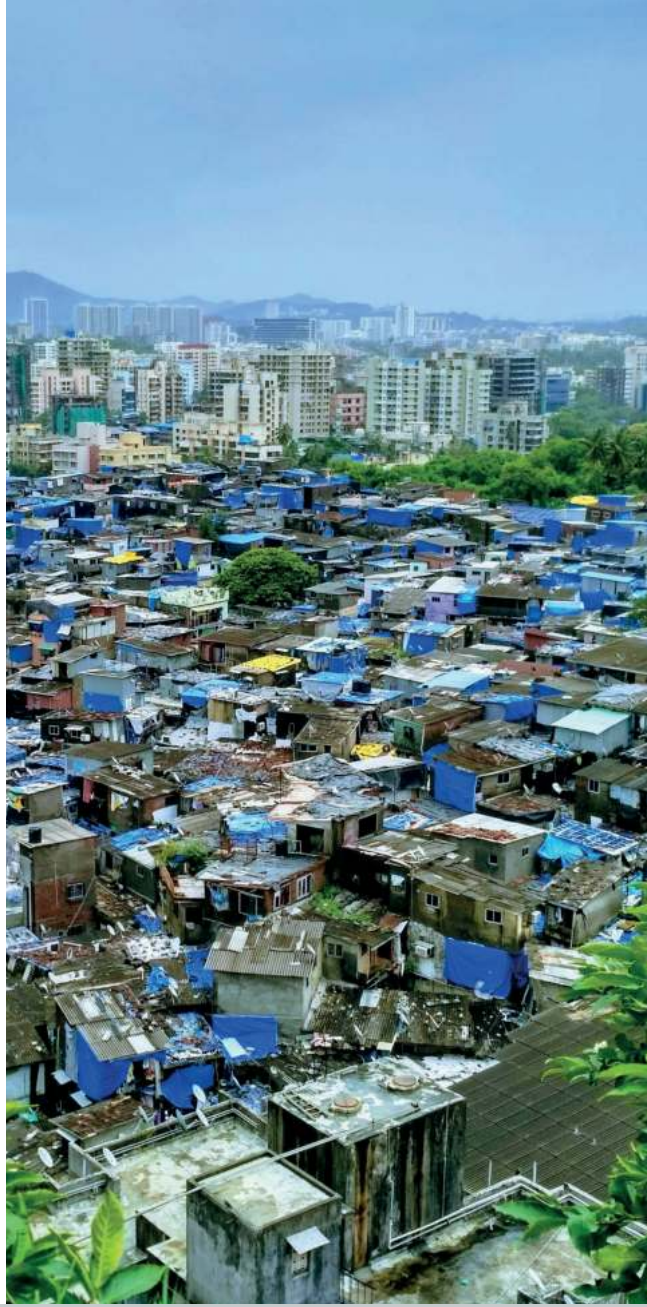
- Urban areas exhibit formal and informal employment opportunities, as cities pool production, distribution, and exchange processes to leverage advantages of centralization of ownership [112].
- Rural-urban migration is facilitated by higher urban income levels, as evidenced by a 2.7-fold higher disposable income level per capita in urban China compared to rural China [113].
- Urban centers are associated with superior educational facilities, easier accessibility of healthcare, and modern housing [114].

Challenges:

- An expansion of informal settlements catalyzes socio-economic disparities and social exclusion within cities [109].
- In combination with the absence of urban governance and poverty, disparities foster urban insecurities and crime rates [115].
- An uncontrolled population growth complicates sustainable urban planning and complicates the provision of fundamental public services (e.g. waste management, sanitation, and health care) [116], [117].
- Inadequate waste management and sanitation infrastructure provide ground for environmental pollution that intensifies climate change and health problems [105], [118].
- Especially for disadvantaged parts of the population, the quality of urban life decreases, as they are directly exposed to health-endangering waste near contaminated sewers and landfills [116], [118].

Impact on the Future of Waste Management:

An increasing urban population constitutes a major challenge for the entire waste management industry [122]. Uncollected and poorly disposed waste harms human health, damages the environment, fosters climate change, and impedes economic growth [105]. In this context, municipalities must define waste management not as a major expenditure item within municipal budgets, but rather as a key lever to improve life quality. Therefore, urban governance needs to (i) provide land to set up and operate waste management infrastructure (e.g. recycling and waste disposal facilities) and (ii) increase the frequency and coverage of waste collection in informal settlements [122]. Especially, in rapidly urbanizing Sub-Saharan Africa, waste management must become the foundation for smart city governance to close the gap between waste collection rates of 45% and a forecasted three-fold increase of waste by 2050 [119], [120].



ECOSYSTEM CONTAMINATION

Pollution Caused by Mismanaged Waste Poses a Big Challenge to Mankind

The global awareness for environmental pollution is increasing with waste mismanagement being one of the most important anthropogenic pollution sources [161]. More than half of the world's population does not have access to regular waste collection, which results in a significant share of informal collection and recycling [162]. The 15% global waste recycling rate reveals that landfilling and open burning remain the main methods of waste treatment and disposal [163], [164]. These predominantly unregulated methods cause serious soil, groundwater, and plant contamination by toxic elements such as chromium, mercury, or zinc [165], [166]. This form of pollution negatively impacts not only biodiversity [167], but also human health, causing diseases such as respiratory infections, high blood pressure, sleep disorder, and cancer [168], [169].

Facts:

- Waste corresponds to the fourth-largest GHG emitting sector in Europe, accounting for 3% of emissions [170].
- Plastics are a major environmental hazard that pollute soil, air, and aquatic life. Since 1950, 92% of globally produced plastic has been disposed of in landfills or incinerated, leading to the release of chemically hazardous materials in the environment, ecological degradation, and threats to biodiversity. More than 660 marine species are affected by plastic residue, contaminating food chains and harming human health in the long run [171], [172], [173], [174].
- 70% of toxic and hazardous chemicals in the environment (e.g. mercury) arise from WEEE, as only 17% of WEEE is formally collected and properly recycled globally [175], [176].

Key Drivers:

- Population growth and higher demand for plastic goods in an emerging middle class will double the amount of globally produced plastic by 2050 [177]. Plastic production and incineration are expected to make up 15% of global emissions by 2050 [178].
- High plastics waste collection costs, lacking adequate waste management infrastructure, and low demand for recycled plastic materials account for 8.8m tons of plastics that are disposed of in oceans annually. Thus, the weight of plastic in the sea is predicted to exceed the weight of fish by 2050 [171], [177], [179].
- With increasing Electrical and Electronic Equipment (EEE) consumption rates and shortening life cycles, WEEE generation averages 7.3 kilograms per capita per year [175]. Further, the annual growth in WEEE generation far exceeds the annual growth in formally collected and recycled WEEE (2m vs. 0.4m Metric tons) [181].

Challenges:

- Waste-related ecosystem contamination endangers human health: Between 400k and 1m people die annually due to diseases and accidents that are linked to improper waste management in developing countries [181].
- The implementation of environmentally sound and effective waste management methods is expensive, accounting for up to 50% of municipal budgets [182], [176].
- 90% of globally produced WEEE is exported to developing countries, which lack WEEE handling and recycling infrastructure. Once there, nearly 98% of all WEEE is managed informally, which can be toxic to the environment and to human health [176].

Impact on the Future of Waste Management:

Improvements in waste management are crucial to lowering humanity's negative impact on the Earth's ecosystem. Especially in developing countries, waste pollution is becoming a major challenge, as pollution impacts not only the ecosystem and human health but also economic factors, such as tourism and fishery [184], [185]. To realize various climate goals and prevent further ecosystem contamination, governments need to radically change waste management practices by increasing recycling rates and transitioning from waste export into domestic waste management [186].

DEMAND FOR CONVENIENCE

Consumers in Today's Fast-Paced Environment Demand a Convenient Consumption Experience

The increase of on-demand offerings and the strong customer focus enhance the consumer's demand for convenience at all stages of consumption [145]. This includes conveniently disposable packaging for to-go food, packaging for bought goods like groceries that eases the transportation, delivery, storage, and usage of the respective goods, as well as sizing for single households, but also convenience within the disposal process [146].
Consumers appreciate any easy way to identify sustainable products when undertaking a purchase decision [147]. The perceived convenience is dependent on factors such as individual preferences, values, and life circumstances [148]. Consumers also differ in their willingness to pay for a pleasant experience [149]. Especially for low cognitive involvement products like groceries consumers choose products out of habit, even though they might have an intention for sustainable behavior [150].
The topic of waste in consumption needs to be addressed with the whole lifecycle in mind. Delivering a satisfactory consumer experience will be a key factor for any successful and collaborative waste management strategy.

Facts:

- About 80% of consumers see convenience as a critical success factor for customer satisfaction [138], and among aspects like price, brand, and perceived quality as the primary reasons for a purchase decision [151].
- The level of actually recycled material is highly dependent on the level of convenience throughout the disposal process, e.g. bins 1.5 meters away from suite doors boost recycling and composting rates by 141 percent compared to bins outside of buildings [152].
- Demand for convenience has increased in several areas, e.g. the convenience food market grew at an annual rate of 4.6% [153] and home delivery amounts increased by around 30% from 2019 to 2020 [154], [155].

Key Drivers:

- Busy lifestyles, perceived time constraints, and higher incomes are the primary causes for comfort behaviors like more out-of-home consumption and the purchase of convenience food [156], which increases packaging quantity [145].
- Decreasing household sizes increase the overall consumption and require smaller buyable amounts of a product resulting in more packaging per amount of product [157].
- The age group of 65+ which will account for 27% of the population in Germany until 2030 requires increasing convenience to pursue an independent life including being able to shop, transport, and dispose of products [158].

Challenges:

- What is perceived as convenient often depends on the individual consumer, which increases the challenge of designing an experience that is commonly agreed upon as convenient [148].
- Higher recycling rates can be achieved by both convenience [152], and incentivization [159]. Determining the successful strategy mix is highly dependent on many contextual factors like income, region, and awareness.
- Consuming low cognitive involvement products requires reusable and recyclable product packaging to be easy to identify and at least equally convenient as the disposable alternative [150] in order to cross the human intention-action gap [160].

Impact on Waste Management:

If measures to reduce the waste amount and improve the overall waste management are inconvenient for the consumer, waste management officials will struggle to enable an overall adoption of society for more responsible waste behaviors. A pathway to success requires all included stakeholders starting with product design to take active responsibility in shaping a convenient and behavior incentivizing experience along the 3R of reducing overall waste, reusing packaging, and recycling used material. If consumers find these processes to be convenient this can significantly contribute to future-proof waste management.

INCREASE IN RESOURCE PRODUCTIVITY

Recycling as an Important Part of the Circular Economy in terms of Efficient Usage of Scarce Resources

Resource productivity, measured as GDP per unit weight of materials used, becomes increasingly important since the Earth's natural resources are becoming increasingly scarce [187], [188]. In particular, the G20 countries, which account for approximately 75% of global material consumption, need to establish resource efficiency and resource circularity strategies [189]. Among the emerging models to tackle the scarcity problem is the circular economy model. It focuses on closing the material loop and maximizing resource productivity by replacing the traditional linear "take-make-dispose" model with the 3R strategy [190]. In perceiving the circular economy model, governments need to focus on keeping materials in the economy for as long as possible, while keeping the value and quality of materials as high as possible. This recycling principle can be applied to all types of products and corresponding types of waste, such as MSW or construction and demolition waste (CDW) [191].

Facts:

- Due to overconsumption, humanity already needs 1.7 Earths to cover the resource demand in an environmentally sustainable way [192].
- The percentage of the global population living underwater scarcity has risen from 14% to 58% over the last century. 92% of total water consumption can be connected to agricultural activities [193], [194]. Eliminating food waste and loss, estimated to account for one-third of total food production, could reduce freshwater consumption by one-fourth and save around 1.2tn USD annually [195], [196].
- The resource productivity of the EU has increased by about 35% since 2000 [197].

Key Drivers:

- Existing economic models rely on the usage of virgin resources [200]. In order to meet the increasing demand for natural resources resulting from rapid economic growth, governments must adopt the circular economy concept [187], focusing on resource productivity [188].
- Climate change is one of humanity's biggest challenges. A more efficient way of using natural resources can reduce the human footprint. For example, high-quality recycling of WEEE allows avoiding a significant amount of GHG emissions, compared to the usage of virgin resources [201].
- With China possessing approximately 78% of the world's rare earth elements (REE) [202], the EU is highly reliant on raw material imports [203].

Challenges:

- Improvement in recycling and sorting technologies are needed to keep the value of the materials at the same level after multiple recycling cycles. For example, currently, only 2% of the total amount of plastics is recycled into the same-quality applications [204].
- Economic profitability is the driving factor for resource recovery rate. In the absence of financial and legal incentives, some types of secondary resources are not recycled at all [205]. For example, the low development of the CDW recycling market is one of the main obstacles to increasing CDW recycling rates in China [206].

Impact on the Future of Waste Management:

Better waste management can help to reduce the use of primary resources and thus increase resource productivity [207]. To achieve higher resource productivity, a restructuring of the entire product value chain is required: Waste management stakeholders will need to cooperate with manufacturers, product designers, and consumers to optimize and extend the product and material life cycle. Product designers will need to move towards waste-avoidant and more recyclable design through smart and transparent design decisions [208].

LEGAL & POLITICAL TRENDS

INFLUENCING THE FUTURE OF WASTE MANAGEMENT

Standardized Regulations to Reduce Waste
Deglobalization in Waste Management Execution
Advancing Extended Producer Responsibility
Rising Legal Attention on Consumers
Increasing Enforcement and Tracking Efforts

Richard Stromer, Nikolaus Pinger, Yulia Lomakina, Alexander Worbs, Stefan Zheng

LEGAL & POLITICAL TRENDS

Influencing the Future of Waste Management

Waste has accompanied humankind since the dawn of civilization. In Germany, waste management has been long regulated through legally defined processes set on the EU, federal, state, and municipal levels. Despite all the measures taken, however, the volume of waste and its detrimental impact on the environment has increased in recent years. Consequently, policymakers have realized that a transition towards a circular economy is essential to minimize waste in the future. A circular economy aims to maintain the value of products or materials and enable green growth in the long-term. The EU fosters its vision of a circular society by issuing directives that European member states implement in their legislation. Based on governmental policies, regulations, and developments, the following chapter identifies legal and political trends that might impact the future of waste management.

To prevent waste before it is created, policymakers are increasingly focusing on unifying waste regulations at federal, European, and international levels. A standardization of waste regulation within the EU aims to create more uniform laws, targets, classifications, as well as competitive conditions for all stakeholders. With its European Green Deal and CEAP, the EU has set up a strategic framework to reduce waste.

Contrary to the lawmaking process becoming more globalized, the execution of waste management is becoming deglobalized. Only five years ago China imported 70% of European waste, but strict import bans have forced developed countries to treat their waste locally and make up for the restricted exports. This currently leads to more intra-EU exports and might result in innovation and better waste treatment in developed countries.

Extended Producer Responsibility (EPR) originated in Germany in the 1990s as the country feared to run out of waste disposal capacities. This imminent problem led public authorities to rethink waste management by transferring some of the responsibility for product collection and disposal to producers. In view of further growing waste volumes, an increasingly deglobalized waste value chain, and major challenges such as the transition to a circular economy, extending this producer responsibility to new products and standards appears necessary.

In addition to influencing producers through EPR, governments will incentivize sustainable producer behavior by requiring more information disclosure regarding product sustainability to consumers, so they can generate greater demand for eco-friendly products. In the near future, consumers might obtain a "right to repair", which is expected to improve the durability of electronic products and minimize WEEE. Moreover, deposit systems have proven to be highly effective in involving consumers to achieve circular economy goals and will be expanded across Europe.

Law enforcement agencies focus their efforts on environmental and economic damages caused by waste crimes. Illegal activities boom on a global level due to growing waste volume and stricter regulations, while yielding high profits and limited risks for criminals. Policymakers consider enforceability and push for better reporting in the waste industry. Based on better data for traceability and more international collaborations, enforcement agencies rally to close the gap between regulations and reality.

STANDARDIZED REGULATIONS TO REDUCE WASTE

Policymakers Focus on Unifying Regulations at Supraregional Levels

Due to the increasing total waste volume over the past decades [209], policymakers have become increasingly aware of the need to prevent waste before it is created [210]. Following the societal push on sustainability [211], policymakers are now focusing on establishing binding recycling quotas and a uniform legal framework on international levels.
Uniform laws, targets, classifications, and regulations not only at a federal level but at national and supranational levels aim to resolve inconsistencies and create the same competitive conditions for all stakeholders [212].
Since the EU waste directive of 2008, which paved the way for this standardization trend [213], the EU has made further plans to promote social, environmental, and economic change and innovation as well as for a global alliance for the circular economy. The European Green Deal and CEAP are the strategic frameworks of these plans that the European member states will implement into their legislations in the upcoming years. This will strongly contribute to the overarching goals of reducing waste and fewer carbon emissions in the future.

Facts:

- Through various directives, the EU has set and tightened recycling targets for different waste streams, e.g., WEEE (2012), MSW (2018), and packaging (2018) [214].
- More than 1tn EUR will go into the European Green Deal and CEAP by 2027 [215].
- In 2021, the Global Alliance on Circular Economy and Resource Efficiency (GACERE) was launched, bringing together governments and relevant organizations from the EU and other countries [216].
- In 2021, the Global Alliance on Circular Economy and Resource Efficiency (GACERE) was launched, bringing together governments and relevant organizations from the EU and other countries [216].
- In contrast to previous elections, all parties currently represented in the German Bundestag have proposals for a more circular economy in their election programs for the 2021 Bundestag elections.are required to be accessible despite impairments [250].

Key Drivers:

- The amount of waste produced annually worldwide is expected to increase by 70% to 3.4bn tons by 2050 due to global economic and population growth, highlighting the need to focus on waste reduction [217].
- The United Nations (UN) agreed on sustainable development goals (SDGs) containing a specific goal on waste management due by 2030 [218].
- Global climate movements such as "Fridays For Future" [219] and green parties demand uniform EU-wide waste regulations while gaining influence in many European member states [220].

Challenges:

- Standardizing waste regulations is a difficult trade-off between the right level of abstraction, overlapping definitions, conflicting stakeholders' interests, and a strong need for simplicity and cost-effectiveness.
- Countries within the EU have different starting points as well as economic and structural capabilities to cope with uniform waste reduction targets set by the EU.
- Stakeholders at the municipal level often find it difficult to comply with unrealistic targets set at national or international levels [221].

Impact on Waste Management:

Standardization plays a key role in the Single Market strategy of the EU and is at the heart of the European project [222]. A uniform regulatory framework for waste management will resolve inconsistencies and establish coherent competitive conditions for all stakeholders active in the EU. Part of these EU-wide uniform rules for waste management will demand more responsibility and adaptations from both producers and consumers. In addition, the share of landfilled and incinerated waste in the EU could decrease as a result of the heightened focus on waste avoidance and material recycling.

DEGLOBALIZATION IN WASTE MANAGEMENT EXECUTION

Exporting Waste will Become Increasingly Regulated Resulting in More Local Treatment

Contrary to the increasing globalization and standardization in lawmaking, the operation of waste treatment is becoming more regional. This deglobalization of waste treatment is driven by strict bans and regulations on both sides: Developing countries are banning waste imports and developed countries aim to export less to achieve sustainability and circularity goals. The most influential regulation was the Chinese import ban on waste in 2018. Additionally, to strict bans and regulations, local waste treatment becomes economically appealing due to the number of jobs created by local recycling [223] and the resources that can be recovered. In this way, geopolitical tensions can be reduced and countries can become less dependent on resources from other countries. At the same time, the prosperity and population of previous net importing countries have increased, and therefore their interest and capacity to take care of low-quality waste of other countries has decreased [224]. Another cause of deglobalization in waste management is the financial and environmental impact of long transportation routes and rising shipment costs.

Facts:

- The Chinese waste import ban under the operation "National Sword" took place in 2018 and removed China from the first place of waste importers. In 2019, 187 countries together agreed in the Basel Convention [225], [226] to fight transboundary shipments of hazardous waste. Consequently, EU waste exports decreased from 300,000 tons monthly (70% of total exports [224]) in 2015 to 150,000 tons in early 2019 [223].
- Other Asian countries are following the trend to ban waste imports (India banned plastic imports in 2019 [227], Malaysia started to send back illegal plastic [228], Thailand plans a ban in 2022 [229]).
- Circular economy Initiatives in developed continents such as Europe promote fewer exports [230].
- Japan, Germany, and the United States (US) were the main net exporters of plastic waste in 2019, while Malaysia, Turkey, and Vietnam were the main importers [231].

Key Drivers:

- Political regulations increase for both, waste importing as well as waste exporting countries [225], [226], [230].
- Geopolitical tension [232] drives the motivation to be independent of other countries for resources.
- Resource scarcity (especially WEEE) drives the motivation to keep valuable material in the country and deploy a circular economy.

Challenges:

- Decreasing export opportunities out of the EU result in an increase of intra-EU waste trade from 2.05m tons in 2010 to 2.58m tons in 2019 [234].
- Decreasing exports will make it harder to reach the recycling goals for Europe since exports mostly count as recycled materials.
- Fewer exports hold the risk of more landfilling and incineration, leading to more waste treatment at lower levels of the waste hierarchy [223].
- Waste trading regulations heavily depend on the classification of waste and therefore leave many loopholes for criminal activities.

Impact on Waste management:

Fewer exports to developing countries will help to bridge the gap in the social divide towards those countries. However, EU internal waste exports will most likely increase. With time, also those exports will likely decrease and will move towards more local responsibility and treatment of waste. Local waste management will also have a positive impact on minimizing CO2 emissions as developed countries mostly have a more comprehensive waste monitoring in place. Overall, the quality of waste management will likely improve due to technical innovation and a higher priority from politics.

ADVANCING EXTENDED PRODUCER RESPONSIBILITY

Producers Are Given More Responsibility to Actively Contribute to Waste Management

EPR is a policy framework that aims to increase product recovery and minimize the environmental impact of waste material. EPR shifts the financial responsibility of waste management from the public sector to producers through instruments like e.g., take-back requirements or taxes [237]. Germany was the first country in 1991 to introduce an EPR system for packaging [238]. Since then, the concept has expanded rapidly to other countries and waste streams. The EU puts EPR at the core of its waste management strategy and requires its members to implement EPR policies for WEEE, End-of-Life Vehicles (ELV), batteries, and packaging [239], [240]. Many member states have implemented EPR policies for further waste categories even without EU obligation [241].
The trend of EPR continues, as it is well suited to create a sustainable production and consumption policy that develops effective recovery channels and sets incentives for eco-friendly product design [242]. Thus, it is seen as a key policy instrument to achieve core EU objectives such as the transition to a circular economy or zero pollution.

Facts:

- The number of EPR policies worldwide has quadrupled in the last twenty years [237].
- The packaging (2020) and single-use plastics directive (2019) obligate all EU member states to implement EPR schemes for packaging and remaining single-use plastics by 2024 [243], [244].
- Various European countries, such as the United Kingdom (UK) and Greece, plan to introduce new EPR schemes for textiles and furniture [245], [246].
- Extending the application of EPR is part of the EU's plan to reach zero pollution from production and consumption by 2050 [247].
- Costs for waste management will become an increasing burden as public spending has already increased by 36% in Germany between 2009-2019 [248].

Key Drivers:

- Key waste streams such as packaging and WEEE, for which EPR schemes have already been proven efficient, increased significantly in recent years [249], [250].
- EPR addresses the entire product lifecycle from design to collection and recycling, making it a crucial instrument to support the goals laid out in the CEAP [251], [252].
- Zero pollution and carbon neutrality require strong commitment and accountability of companies for their actions, for which EPR can provide the legal basis [253], [254].
- Germany has to take more responsibility for its waste due to export and landfilling limitations; rising costs of waste management make delegating this responsibility to producers an attractive alternative [255], [256].

Challenges:

- Unclear and overlapping responsibilities between public bodies, producers, and PROs within EPR schemes constitute governance and administrative challenges [242].
- EPR creates incentives to recover material from waste but usually does not contain specific incentives for the reuse and reduction of waste [257], [237].
- Assessing the cost-effectiveness of EPR policies is difficult as benefits are hard to quantify and EPR schemes usually are very specific which hinders their comparability [237].

Impact on Waste Management:

Further advancing EPR schemes in Germany and Europe is considered a promising strategy to achieve higher collection and recycling rates for key waste streams such as plastics or WEEE [259], [260]. In line with this, EPR has so far proven to be an effective instrument to realize parts of the EU circular economy goals, particularly in the field of material recovery [261], [257]. As it shifts financial responsibility from public authorities to producers, the overall public spending on waste management can be expected to decrease [237]. On the product side, scholars generally agree that EPR policies provide valuable incentives for better, more eco-friendly product design [235], [236].

RISING LEGAL ATTENTION ON CONSUMERS

Political Institutions are Giving Consumers More Opportunities to Impact Waste Management

Consumers are increasingly becoming contributors to the circular economy since they can execute high market power to generate demand for sustainable products and services [262]. The new CEAP adopted by the European Commission in 2020 introduces the "Consumer Agenda" that will increase the transparency of information regarding the energy efficiency of products, raw materials, and further recycling possibilities [263]. Consequently, more transparent information will empower consumers to make better informed purchasing decisions for eco-friendly products [262].
The plan also addresses the public concern about the short durability of tech products by giving consumers the right-to-repair with the purchase of new electronic devices. The right-to-repair constitutes a key step to increase the product lifespan and minimize WEEE which has hazardous effects on the environment [264]. In addition, as circular economy principles and new packaging regulations require products to be returned for further processing, governments in many European countries are introducing or expanding deposit systems [265].

Facts:

- Under the CEAP, the European Commission will emphasize substantiating environmental claims made to consumers by including more durability and recyclability content in the EU Ecolabel criteria [264].
- Starting 2021, the new regulations under the EU's Ecodesign framework will require manufacturers to design repairable machines, dishwashers, refrigerators, televisions (TVs), and lighting [267].
- The European Parliament also plans to extend the right-to-repair rules to smartphones, tablets, and laptops [268].
- Deposit return systems are active in 10 European countries; 12 additional countries will introduce similar schemes by 2023, and Germany will extend its system to all cans and bottles made from disposable plastic in 2022 [265], [269].

Key Drivers:

- The majority of Generation Z and Millennials prefer sustainable products, but lack of transparent information often prevents them from leveraging their purchasing power and putting pressure on producers to become more eco-friendly [270], [277].
- EU consumers showed a strong preference for improving electronic product repairability, as more than 70% of EU citizens would choose repair over replacement [271].
- Stricter regulations regarding packaging waste, such as the EU Directive 2018/852, and the adoption of the CEAP increased the need for end-of-life product collection from the consumer side [264], [272].

Challenges:

- Eco-friendly products often lack affordability, which prevents consumers from choosing sustainable products despite the availability of information [273].
- Apple, Microsoft, Google, and Amazon are lobbying against the right-to-repair, arguing that it would compromise data security since more people with access to repair tools could steal data [274].
- Current deposit systems require considerable investments to increase the operational speed, reduce possible queues, raise system throughput and improve consumer satisfaction [275].

Impact on Future of Waste Management:

Overall, involving consumers in the waste management system creates a sense of shared responsibility among governments, consumers, and business players that is crucial for achieving circular economy goals [276]. With more transparent information and a right-to-repair, consumers are expected to increase the demand for sustainable products with high durability and recyclability, which would help to minimize waste disposal, especially in the WEEE category [262]. Furthermore, the introduction and expansion of the deposit systems are also expected to stimulate an increase in general packaging waste recycling rates [275].

INCREASING ENFORCEMENT AND TRACKING EFFORTS

Enforcement Agencies Rally to Close the Gap Between Regulations and Illegal Activities

The growing gap between stricter regulations and increasing illegal waste activities emphasizes the need for better tracking and enforcement systems [278]. As inherent to unlawful activities, the extent of this issue is hard to quantify, but the damages to the environment, public health, and economy are evident [279]. Regulations, such as the Basel Convention, lay the foundation regulating waste transports, focusing on hazardous materials that require all countries' confirmations [280]. Increasing recycling quotas and trade bans make illegal alternatives to waste disposal more attractive to maximize profits [281]. Inconsistent regulations across countries and increasingly complex legislation open various opportunities for exploits [282].
To combat the expansion of criminal activity, many governments strengthen law enforcement agencies[285] and collaborate with the International Criminal Police Organization (INTERPOL) to coordinate cross-border operations and mitigate incorrect waste reporting [283], [284]. Repeated special operations [286], [287], [288] put pressure on illegal activities and provide a snapshot of what is happening [289].

Facts:

- The EU listed illicit waste trafficking as one of the most pressing criminal threats since 2010 and renewed its importance for 2018 and 2021 [290], [291].
- The World Customs Organization and UN launched a new initiative in the container control program (CCP) [292], [293] to improve enforcement agencies' capacity to counter illegal shipments of plastic and hazardous waste trafficking in 2021 [294].
- The UK launched the Joint Unit for Waste Crime (JUWC) as a dedicated coordinated task force to target waste criminals in 2020, which reported several successes over their first year in service [295], [296].

Key Drivers:

- Environmental crime is the 4th most lucrative illegal business with an estimated 258bn USD annually and projected future growth [297], causing economic damages worldwide [298], [299], [300].
- The globally growing waste volume and stricter regulations lead to an increasing illegal waste dumping and trafficking [301], visible in thousands of illegal waste shipments per year [282], [302]
- The pollution from illegal waste dumping and leakages poses a growing danger to our public health and environmental ecosystems [279], [303], particularly affecting socio-economically weaker people [304], [305].

Challenges:

- A lack of international communication about rapidly changing waste regulations creates uncertainty about enforcement activities and responsibilities among stakeholders [282], [306], [307].
- The absence of standardized shared data prevents informed priorities of enforcement actions and obscures the real impact of waste trafficking [289], [298], [304].
- Criminals often operate legitimate waste management companies to disguise the origin of their illegal funds and mix toxic substances within falsely classified waste shipments [278], [282].

Impact on Future of Waste Management:

The current efforts to connect national law enforcement agencies will continue through coordinated international operations, knowledge exchanges, and shared databases [285], [289], [309]. Policymakers push the industry towards standardized reporting and a more digital supply chain [310] to exchange high-quality data. Enforcement agencies strengthen their influence by consulting lawmakers to close regulatory loopholes and ensure the effectiveness and feasibility of new policies [285]. With better tracking and enforcement, the economic incentive to conduct illegal activity is likely to decrease as UK efforts show a return of 5 USD for each 1 USD invested [311].

ECONOMIC TRENDS

INFLUENCING THE FUTURE OF WASTE MANAGEMENT

CHANGING PRICE STRUCTURES
VERTICAL INTEGRATION
CHANGE IN THE EMPLOYMENT MARKET
CHANGING RESPONSIBILITY DYNAMICS
DESIGN FOR RECYCLING

Sebastian Serna Figueroa, Leonie Wagner, Christopher Voit, Frederik Junge, Agnes Kocsis

ECONOMIC TRENDS

Influencing the Futre of Waste Management

Waste disposal, processing, and recycling are heavily dependent on economic developments. In order to look into the future of waste management, it is therefore essential to understand the driving forces influencing these developments.

The growing amount of waste forces authorities and waste management services (WMS) to improve pricing schemes for waste processing and find efficient ways to distribute responsibilities between municipalities and private contractors. New jobs in the circular economy are created to meet the new recycling quotas in the EU and counter the effect of China's import ban on solid waste. Looking at the increasing scarcity of resources, such as oil and coal, companies are motivated to find profitable business models and manufacturing processes that efficiently recapture the value of recycled materials. Building on these developments, we have discovered five trends that showcase the role of the economy in the future of waste management.

To hit recycling quotas and to adapt to an increasing minimum wage in almost all EU countries, WMS are adjusting their pricing structures for waste disposal, processing, and recycling. Using Differential-Variable Rate (DVR) charging systems, waste producers are more accurately charged for the type and amount of waste produced. Deposit-refund systems (DRS) and advanced recycling fees increase product prices and act as incentives for consumers to return used products and opt for easily recyclable products, respectively. The increasing demand for recycled products also forces original equipment manufacturers (OEMs) to rethink their approach to the product value chain, looking to have a stronger market position and producing higher quality recycled products at a lower price. This results in an increase in mergers and acquisitions (M&A) activity in which OEMs join forces with recycling companies further up and down their supply chain. This also increases the knowledge transfer between manufacturers and waste processors, paving the way for innovative approaches in sustainable product development. Regulatory changes regarding waste disposal and processing on the EU level also facilitate changes in the job market for WMS and recycling companies. Shifting from traditional disposal methods, such as incineration, recycling, introduces a demand for a new workforce. A more circular economy will also require workers to handle low-skilled tasks, such as waste sorting, and highly skilled ones, such as consumer product repair. When faced with increasing amounts of waste, public authorities are forced to distribute waste collection and processing effectively. Following the unvalidated claim for cost-effective and high-quality services, many countries choose to outsource their WMS to private contractors. However, a contrary development can also be observed in Germany, where municipalities are increasingly reintegrating WMS. This in-sourcing gives cities the flexibility to adapt to environmental and economic specificities. Finally, as raw materials are getting scarcer, the demand for recycled products increases. Manufacturers are increasingly partnering up with WMS and other actors along their supply chain to understand how their design and development processes impact a product's recyclability. This growing openness for cooperation positively impacts the quality of secondary raw materials and the profit margin of recycling companies.

CHANGING PRICING STRUCTURES

Companies are Increasingly Following the Principle of "Polluter-Pays"

Flat-rate charges for waste disposal are still common in many European countries, such as Ireland and Greece [312], [313]. However, these single-fee charges cannot cover the increasing costs of processing the growing waste throughout the last years [314]. This cost pressure is further reinforced by new recycling quotas introduced by the EU, pressuring companies to invest in new recycling infrastructure [315]. As a result, WMS are increasingly moving the added cost to the waste producers. This shift can be observed in the introduction of DVR charging systems, DRS, or advanced recycling fees by WMS and product manufacturers, respectively. DVR systems charge for waste type in combination with the amount and incentivize waste producers to reduce their waste generation. DRS and advanced recycling fees increase the price of a product by a certain percentage. This added charge of DRS will be refunded to buyers upon successful disposal of the used product. Advanced recycling fees function as a cost-effective income for waste collectors to fund the recycling process of the product [316].

Facts:

- By WMS, DVR charging systems are increasingly adopted in countries such as Belgium, Denmark, Finland, Germany, and the Netherlands [317].
- Member states of the EU are obliged to adhere to the capped landfill disposal rules set in 2018. This directive aims to pressure WMS to opt for incineration and recycling processing instead and, therefore, reduce their environmental impact [315].
- 24 of the 27 EU member states saw an increase in waste disposal fees over the last years, with prices more than doubling in Poland between 2018 and 2020 [318].

Key Drivers:

- The biggest driver for this development can be found in the latest Waste Directive of the EU, which forces its member states to hit recycling quotas of 65% by the year 2035, thus increasing the pressure on WMS to invest in recycling processes [315].
- An increased minimum wage in almost all EU states drives the need for higher waste disposal fees to cover the increasing personnel costs [319].
- Municipalities and WMS need to invest in infrastructure to deal with the increasing amount of household and commercial waste. To cover the resulting costs, public and private operators are passing them to waste producers [320].

Challenges:

- While DVR charging systems follow the "polluter-pays" principle, they introduce high revenue volatility as waste charges directly depend on waste generation [316].
- Weighting systems that allow for accurate measurements are expensive and complex to operate [316].
- The introduction of DRS requires infrastructural and behavioral changes since individuals need to adapt to returning used products.
- Introducing an advanced recycling fee might lead to high administrative costs as the fee needs to be constantly adjusted for changes in product development and pricing [316].

Impact on the Future of Waste Management:

Introducing more efficient waste collection fees might lead to reduced waste generation, as producers will try to minimize their costs for disposal. Coupled with a flat-rate charge, this could make illegal dumping economically unattractive as every waste producer is forced to pay a basic fee regardless of their waste production. Additionally, WMS could be able to cover their costs better and predict revenue flows. While DRS do not seem to change buying behavior, they allow for increased collection and recycling quotas. Together with an additional recycling fee, buying behavior could be addressed effectively, as sustainable products would be cheaper than those that are more difficult to recycle [316].

VERTICAL INTEGRATION

M&A Activities to Integrate Companies Up- and Downstream of the Value Chain

The waste management industry depends on raw material manufacturers to buy recycled commodities to use in new products. Current systems are designed to benefit producers and are counter-productive for a circular economy as waste management companies are paid per weight and have no incentive to optimize for quality demands [321]. Especially in the fast-moving consumer goods market, the supply chain is highly competitive. Companies tend to have no interest in a close relationship with their partners up- or downstream and focus primarily on their business model. In the last five years, however, stakeholders have begun to acquire companies in their supply chain to gain synergetic advantages. This can be seen in the example of the Schwarz Group and their PreZero foundation in Europe buying waste management and recycling companies across their value chain [322]. This approach follows the understanding that successful sustainability needs to be competitive and, therefore, economically viable. By improving the value chain for recovery, processing, and manufacturing commodities, stakeholders invoke a system-level change that leads to altered cost structures and revenue flows for all participating companies [323].

Facts:

- Vertically integrated companies show significantly higher profit margins and pricing power in the WMS sector [353].
- The current care gap is estimated to be of 140,000 workers in Germany [339, p.11]. The Bertelsmann Foundation projects the gap to grow to almost half a million care workers in Germany by 2030 [336].
- Member states of the EU are obliged to adhere to the capped landfill disposal rules set in 2018. This directive aims to pressure WMS to opt for incineration and recycling processing instead and, therefore, reduce their environmental impact [315].
- 24 of the 27 EU member states saw an increase in waste disposal fees over the last years, with prices more than doubling in Poland between 2018 and 2020 [317].

Key Drivers:

- The global waste management market is fragmented and highly regional, but in recent years several companies have tried to build multinational firms by acquiring competitors and suppliers [326].
- Synergy effects, such as higher quality products, can be achieved when focusing on the whole supply chain and sharing data between stakeholders [323].
- Companies who have distributed ownership along the value chain have a long-term competitive advantage as shared knowledge between players makes recycling quotas easier to fulfill [323].

Challenges:

- The integration of companies up- or downstream poses technical and economic challenges. Depending on the geographic region and the integration application, specific know-how is needed to resolve them successfully [327].
- An adaptation of packaging will have to take brand perception into account, as consumers are sensitive about the look and feel of products [327].
- This approach has high entry barriers, as major funding is required to acquire companies along the supply chain [328].

Impact on the Future of Waste Management:

Circular and holistic approaches to post-consumer recycling will change how the recycling industry operates. Utilizing data-driven approaches and economies of scale enables the industry to increase recycling quotas and improve quality. This leads to higher profit margins and less waste generation along the supply chain. Vertically integrated companies have increased market power and can enforce change on other stakeholders further up- and down the supply chain. This power enables them to shift towards a more sustainable approach in the packaging industry and help prepare the sector for stricter regulations, such as higher recycling quotas, in the next decade [312].

CHANGE IN THE EMPLOYMENT MARKET

Transition Towards a Circular Economy as an Opportunity for the Job Market

Today's economy is mainly based on a linear model in which products are manufactured from natural resources and discarded after usage [329]. By shifting towards a circular economy, the recycling, reuse, and repair of products will increase, leading to three main changes in the employment market. First, the number of jobs in waste management will increase. Activities involving recycling, reuse, and repair are more labor-intensive than disposal methods such as landfilling or incineration. This is because taking care of existing products requires more workers than often highly automated mining and manufacturing processes [312]. It is estimated that 700,000 new jobs can be created by 2030 as a result of the CEAP of the EU [330]. Secondly, depending on the activity, the skill level in future waste management employment will vary. Low to intermediate skills will be required for recycling processes, while repairing requires product expertise and higher skill levels [312]. Thirdly, the shift to a circular economy will lead to a fragmentation of the system into smaller, autonomous parts. While large incinerators and landfills are often organized in centralized structures, circular economy systems tend to be decentralized and rely on local community led organizations [331].

Facts:

- Repair and recycling processes require a bigger workforce than landfilling and incineration. While recycling employs 36 workers per 10,000 tons of waste per year in the EU, landfilling employs only 2.5 workers [331].
- Out of the 3.4m employees in Europe in circular economy activities in 2012, only 20% deal with waste collection and treatment, while the majority includes repair and rental activities [332].
- The Integrated Resource Recovery Center model targets waste management in a decentralized manner using reduction, reuse, and recycling techniques. Applying this model in cities of Asian and Pacific regions has shown savings of 2.2m3 of landfill volume per one ton of waste [333].

Key Drivers:

- The EU's CEAP of March 2020 is a main driver for the circular economy. Member states are obliged to encourage the production of recyclable and repairable products and reach recycling quotas of municipal waste of 65% by the year 2035 [315], [334].
- Resource scarcity increases interest in the circular economy. Thus, there is a demand for a resource saving economy favoring the recovery of valuable materials [335].
- The EU plastic export ban from January 2021 drives the shift towards a circular economy. The goal is to avoid waste exports to developing countries where standards for sustainable waste management are often low and promote recycling in local EU facilities [336].

Challenges:

- The future labor market in waste management is still largely uncertain. Due to increased automation and product material enhancement, the employment potential can be overestimated [330].
- No recycling process has been developed yet for some materials, such as cement, that can restore the original quality. In addition, for some materials, such as metals used in compounds, the energy required for recycling is greater than for virgin production [335].
- Due to the demographic change, the working age population is shrinking in the EU [337]. The increasing demand for labor may be difficult to meet.

Impact on the Future of Waste Management:

The shift towards a circular economy might have profound effects on the future of waste management within the next five years. Due to the growth of the recycling, reuse, and repair industry, diverse and differently skilled jobs will be generated. Furthermore, the current central organization of the collect-and-disposal system will split up into a variety of local organizations. Instead of processing waste in large incinerators and landfilling facilities, fragmented community led institutions will take care of it on a local level [331].

CHANGING RESPONSIBILITY DYNAMICS

Privatization and Remunicipalisation as Contrary Developments for Waste Disposal Responsibilities

Public authorities can choose to deliver WMS through either municipally owned services or private contractors. Many European countries increasingly opt for the latter as they expect private companies to provide higher quality services at a lower cost, a claim not backed by evidence until today [338]. Liberal economic regulations and insufficient financial resources for operating publicly backed WMS further support this development [339]. While the shift in responsibilities is expected to stimulate the local economy through competitive structures, it also introduces the risk of monopolistic structures abusing their market position [338], [340]. Conversely, a trend of remunicipalisation, putting responsibilities for WMS back into public hands, can be observed in Germany. The limited regional scope of this change can be explained by Germany's federal structure that allows smaller regions to independently decide on the responsibilities in providing their public services [339]. Publicly operated WMS has the potential to reduce public spending and increase working conditions [340]. Process and industry knowledge previously possessed by private companies needs to be regained by municipalities to facilitate this change of responsibilities successfully.

Facts:

- Two of the biggest private waste management companies, Suez from France and Remondis from Germany, reported a 10% increase in revenue each year between 2014 and 2018 [341], [342].
- The share of private WMS companies in Sweden shifted from 30-40% in the 1990s to 71% in 2015 [334].
- In Germany, around 90% of cities with more than 100,000 inhabitants manage their waste through public services [340].
- While many WMS were outsourced in Germany in the 1980s and 1990s, over 150 cities had reintegrated their services into municipalities by 2010 [339].

Key Drivers:

- Public authorities expect that privatizing WMS leads to competition, resulting in higher pressure to increase efficiency and deliver higher quality services at a lower price. [338].
- Public procurement laws enabling private companies to tender for public contracts lead to these companies winning the bid over in-house providers. In certain countries, such as Poland, public WMS were even prohibited from taking part in such biddings until recently [343].
- The expiration of private contracts for WMS enables municipalities to move services back in-house to increase operations flexibility and reduce spending [339].

Challenges:

- The cost-effectiveness of privatizing WMS remains to be proven empirically, indicating a negative effect on service quality, environmental impact, and working conditions [338], [339], [340].
- Increased outsourcing to multinational companies might lead to monopolistic structures in the waste market. This could foster the emergence of corrupt actors, as observed in Spain and Poland [338], [340].
- Reintegrating waste services into municipalities could further fragment administrative structures and introduce opaque waste disposal rules for citizens frequently moving between different municipalities [339].

Impact on the Future of Waste Management:

The increased privatization of WMS could lead to higher fees, as companies will try to shift the costs of waste disposal to producers [318]. While increased private contract work might boost the local economy and create competition, it might also build up monopolies leading to nepotism, fraud, and corruption [344]. Following the trend of municipalization of WMS in Germany could lead to better working conditions, cheaper fees, as well as the flexibility to address local economic and environmental specificities [339]. While this trend can currently only be observed in Germany, municipalization could spread to different countries following the successful case study of Germany [340], [339].

DESIGN FOR RECYCLING

Change in Product Development to Incorporate the Whole Lifecycle

Traditionally product development did not involve stakeholders down the value chain, such as waste management companies. As resources get scarcer and consumers become increasingly aware of sustainability, companies shift their focus to a more holistic approach in product development and materials acquisition. As manufacturers are increasingly held liable for their product and packaging waste as part of the EPR, they begin to cooperate more and more with recycling companies and packaging producers to solve economic and product development challenges [345]. Companies choose this approach to cost-effectively simplify the recycling process and adapt to increasingly stricter environmental policies worldwide. The main objective is to use mono-materials over hybrids where it is viable [346]. For example, the companies Mondi and Werner & Mertz cooperate on a cleaning solution packaging (85% of plastics recyclable) with a 70% energy advantage over traditional packaging [347]. An increasing number of companies could use this approach in the future to gain a first-mover advantage against competitors forced to adapt to regulatory changes in the coming years [348].

Facts:

- With growing consumer demand for sustainable products, companies are starting to evaluate the return of a product after its lifetime as part of their business model [348].
- In a large market with many participating actors, the economy of scale can be a viable driver for change [329].
- The processing costs of a given product are directly dependent on the percentage of recyclable material included [349].
- Currently, 95% of plastic value is destroyed after first use in the EU, accumulating 70bn-105bn EUR of losses for the economy annually [341].

Key Drivers:

- The prices of raw materials, e.g., oil for plastic, are volatile and expected to rise further in the near future. This poses risks for companies upstream [329].
- Companies are aware that public opinion about sustainability is a major factor for consumer habits and, therefore, adapt their product properties and marketing strategies accordingly [350].
- Current regulations encourage the use of mono-material over material mixes in product manufacturing. Evidence for this can be found in the ban of single-use plastics imposed by the EU and more countries restricting the import of waste [334].

Challenges:

- These business models are not yet profitable, as more companies need to switch to this type of packaging to effectively benefit from economies of scale [348].
- Since most waste management companies operate on a regional level, the value chain is fragmented, leading to challenges for procurement [351].
- Uncertain future regulations could have a significant impact on manufacturers. More bans of production materials, as well as CO2 taxation, have the potential to further complicate value chain operations [352].
- As stakeholders need to cooperate, potential trust issues can occur in the industry (e.g., tit-for-tat theory).

Impact on the Future of Waste Management:

The recycling industry can massively profit from closer cooperation with the stakeholders upstream, as this trend is driven by manufacturers and their need for change. Based on the recycling quotas driven by sustainability policies in most developed countries, especially concerning consumer goods, this trend can be expected to rise over the next few years. As more manufacturers engage in this kind of cooperation, economies of scale will have a substantial impact on this development. This could lead to higher availability and quality of recycled raw materials, improve the profit margin of recycling companies and support them in fulfilling local environmental policies.

BUSINESS MODEL TRENDS

INFLUENCING THE FUTURE OF WASTE MANAGEMENT

Data-Driven Services
Recycling-as-a-Service
Reverse Logistics
Value-from-Waste
Sustainability Certifications

Sophia Escheu, Anna Spitznagel, Emanuel Johannes Gerber, Aqib Shahab Ansari, Júlio Arend

BUSINESS MODEL TRENDS

Influencing the Future of Waste Management

The world's population is growing and with it the consumption of the earth's raw materials. However, the current reserves of crucial resources are limited and cannot ensure long-term supply. This need for a continual resource loop currently transforms the operations of companies across different industries and countries. Increasing consumer pressure drives firms to develop innovations that increase resource efficiency and adapt their business models to the needs of a circular economy.

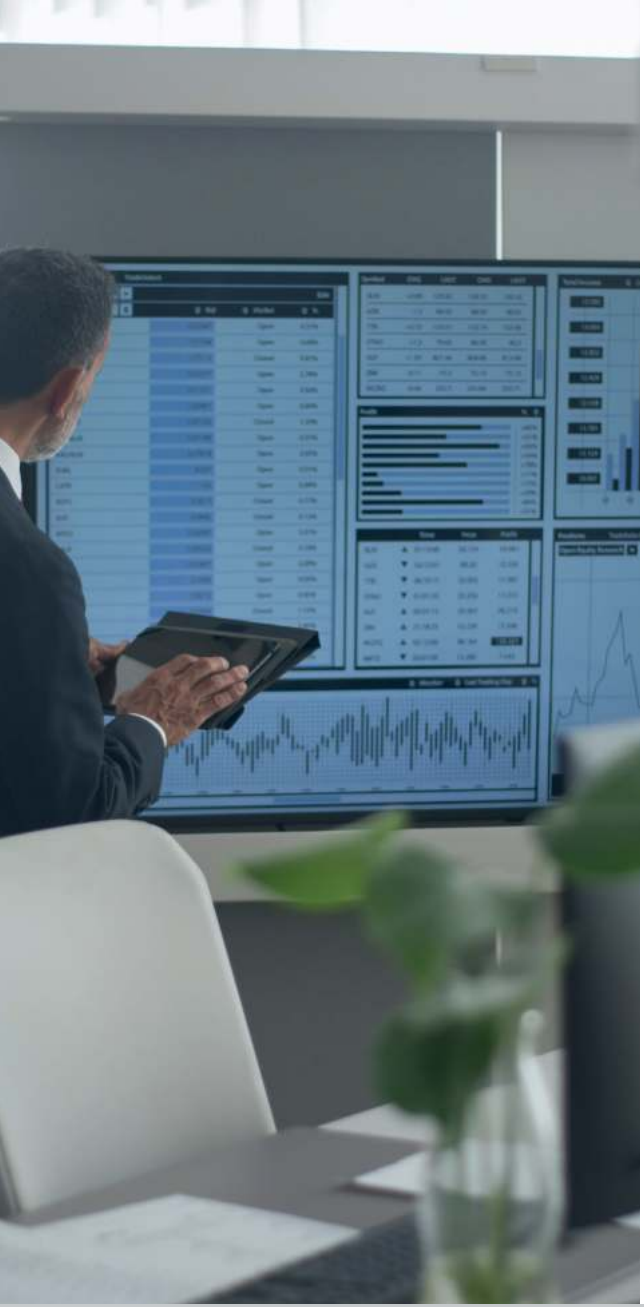
Data-driven business models have been unlocking new revenue potential across many industries in the past years. These revenue streams have been generated by effectively utilizing valuable insights from collected data to improve companies' decision-making. In waste management, data-driven services facilitate the crucial tasks of waste collection, transportation, and sorting by analyzing lifecycle data of prevalent waste streams and by connecting the right actors along the value chain.

Optimized waste sorting sets the basis for innovative material recycling methods with a large variety of possible applications. Similar to various other business segments such as mobility, media, or business to business (B2B) software, companies are following the trend of recycling-as-a-service (RaaS) based processes to decrease dependence on commodity prices and increase profitability. Even though profitability is often the main driving factor for business model change in the waste management industry, companies also have to adapt their activities to economical, technological, and societal changes, as well as to follow the different governmental regulations on environmental protection. These factors not only form the basis for new businesses to enter the market but also challenge established businesses to continuously revise and adapt their existing value propositions. In the following, five business model trends anticipating the "Future of Waste Management" will be introduced to point the way forward into a circular business environment.

Motivated by new potential revenue streams, manufacturing companies increasingly understand how to generate value from products after their end-of-life has been reached. Instead of designing a linear life cycle for their products, manufacturers are engaging in a service based approach to manage their products beyond their first sale, via reverse logistics.

Flexible recycling services, as well as business models including reverse transportation mechanisms, enable new players to develop innovative value creation methods, unlocking new revenue streams through the sale of products manufactured from materials originally declared as waste. Value-from-Waste business models, therefore, help to divert tons of waste material from landfills.

The underlying trends in business models for more circular waste management will further increase the complexity of the industry due to additional stakeholders involved in the end-to-end process. With ambitious regulations and public pressure induced by an ongoing shift of the global mindset towards sustainability, a high waste management quality must no longer be solely performed, but also communicated transparently. Waste management certifications assessing all the activities along the value chain have therefore created another business opportunity in this vivid field.



DATA-DRIVEN SERVICES

Collecting and Analyzing Data of Waste Management Processes

Waste managers, producers, and regulators lack a holistic understanding of prevalent waste streams, waste composition, and optimal further downstream processes. Data service providers therefore increasingly enter the waste management industry by collecting and analyzing data during waste collection, sorting, and processing. This structured and analyzed data empowers municipalities and specialized companies to make more sustainable and economically viable decisions at every stage of the value chain. Startup activities in this field cover a number of different domains: optimizing collection routes, collection frequency, and vehicle load based on fill level data of bin sensors [355], [356], advanced waste sorting through computer vision supported by robotics [357], [358] and connecting the right upstream and downstream players through a centralized platform based on the products' analyzed lifecycle data [359], [360].

Facts:

- Since 2009, a combined 600m USD of VC funding has been invested in ten smart waste management startups to accelerate AI-driven waste sorting and route optimization for waste collection [361], [362], [363], [364], [365].
- Data-driven companies are 23 times more likely to acquire customers, nine times more likely to surpass competitors in customer loyalty, and 19 times more likely to remain profitable [366].
- A case study has shown that data-driven waste management reduces waste collection and transportation costs by 50% by reducing the number of waste trucks on the road and the time drivers spend collecting and transporting [376].

Key Drivers:

- The increasing number of smart city initiatives drives the global interest in smart, data-driven waste management solutions [366].
- Society's increasing awareness regarding sustainability results in an increasing demand for waste management to be more transparent and more effective, which drives the utilization of industry 4.0 technology in waste management [369].
- The high operational costs for collecting and transporting waste also lead to an increased demand for efficient, data-driven waste management solutions which are designed to cut the costs [367], [370], [371], [372].

Challenges:

- Complex waste streams of mixed materials make efficient, data-driven sorting in real-time a technically demanding task [373].
- High costs for advanced sorting technology prevent small and medium sized enterprises (SMEs) from using it on a large scale [374].
- Due to non-standardized ways to collect and assess waste data, comparability is not given yet. Developing unified data-driven solutions is, therefore, a major challenge [373].
- Data-driven support in waste management will be difficult to implement in rural areas and developing countries due to inadequate information and communications technology (ICT) infrastructure [374].

Impact on the Future of Waste Management:

To ensure more efficient and effective treatment of the complex waste, established waste activities will be extended through data-driven services provided by new specialized businesses.
Data-driven services utilizing state-of-the-art computer vision and data analytics technology will serve as a tool to empower municipalities and enterprises to take the next step towards a circular waste treatment approach despite prevalent, counteracting megatrends such as urbanization or individualism in product development. Along with ICT infrastructure continuously expanding to rural areas as well as developing countries, the positive impact of data-driven waste management on health, economy, and ecology will further increase in the future [375].

RECYCLING AS A SERVICE

Improving the Profitability of Recycling by Utilizing a Fee-For-Service Business Model

Recycling is of enormous importance to the circular economy, but it still faces issues regarding profitability. The predominant recycling business model is a purchase model, where recycling companies buy waste and make revenue from selling recycled commodities. This results in a high dependency on end-market prices and therefore often incurred losses. However, the shift in the mindset of all stakeholders towards a circular economy and the willingness to pay for the recycling service is providing an opportunity to introduce a fee-for-service business model. This implies that municipalities, companies, or individuals pay the recycler for fulfilling the service instead of being paid for the waste. These contracts at times also include splitting the sale profits afterward [377]. New companies have emerged to offer RaaS for communities around the world that did not have access to recycling facilities before and enable them to participate in the circular economy. In addition to that, the service character is expanded to offering on-site recycling services to enable recycling at the source. This is especially growing in popularity and importance for CDW [378], [379], which makes up approximately 36% of the total European waste [380].

Facts:

- RaaS has proven to be a successful strategy for startups, like TerraCycle, which generated 25m USD yearly revenue in 2020 [382], but also big players like Waste Management Inc. whose shift to a fee-for-service structure resulted in a more successful recycling performance [383].
- The investments in the German recycling industry more than doubled from 263m EUR to 546m EUR in the five years between 2015 and 2019 [384].
- The recycling rate of municipal waste in the EU steadily increased over the last two decades from 25% to 47% [385], showing its growing importance.

Key Drivers:

- Increasing residential single-stream programs, that allow consumers to conveniently put all recyclable materials into one bin, have greatly improved recycling volumes [377].
- Many initiatives, for example in the building industry, are emerging to build a stable market for recycled products [386].
- Landfills are shrinking in capacity, for example, Germany's landfills are estimated to be full until 2026 [387], which emphasizes the urge towards more recycling.
- The EU, as well as other governments, realize the importance of a circular economy and increasingly incentivize, as well as demand recycling [388], [389].

Challenges:

- Recycling companies typically depend on the commodity market prices, even when enhancing the fee-for-service models [377]. This is a disadvantage compared to the still more profitable landfills [390].
- In many rural communities worldwide, no recycling infrastructure and therefore no access to recycling facilities exist [391].
- Recyclable materials are often lost because there is no obligation to sort residual waste [392]. This problem deteriorates with a growing urban population [393], as waste sorting is less predominant compared to the rural population [390].

Impact on the Future of Waste Management:

The general change in the mindset of all stakeholders towards the responsibility of participating in the circular economy allows recycling companies to shift their business model. Utilizing the rising willingness to pay for recycling services enables the implementation of a fee-for-service business model. It reduces the dependence on commodity prices and therefore enables recycling companies to become profitable while replacing current environmentally unfriendly waste management methods. This will pave the way for other business models revolving around recycled material production and closed loop manufacturing.

REVERSE LOGISTICS

Changing Value Propositions from Product to Service

The contemporary business model of most companies involves one single customer touchpoint [394]. Building on newly introduced producer-responsibility policies, increasing resource scarcity, and growing customer attention on supply chains, an increasing number of manufacturers are starting to manage products beyond their first sale [395], [396], [397], [398], [399]. This means companies across many different industries are shifting their value propositions from one-time product sales to a service model, expanding their offerings to product return and recovery. Their services can include the collection, disassembly, and reassembly of the recovered materials [400]. Examples for reverse logistics services are take-back programs [395], repair services [402], reusable packaging [403], and product leasing [397]. They combine environmental and economic incentives for manufacturers through keeping the used materials in a closed loop while generating major business benefits such as increased brand loyalty, user insights, and cost savings [404], [405], [406], [407].

Facts:

- The size of the total reverse logistics market increased from 233.5bn USD in 2015 to 318.8bn USD in 2019 [407], with the market for reusable packaging making up 40.5bn USD in 2019 [413].
- Corporations in various industries like electronics, fashion, and consumer goods are increasingly introducing take-back, repair, and reuse initiatives [395], [396], [397], [398].
- The volume of products per company that is collected via reverse logistics for reuse, repair, or recycle is growing year on year [409], [410], [411], [412].

Key Drivers:

- Corporate Social Responsibility (CSR) initiatives, as well as the increasing need to preserve a green, customer-focused image, have proven to be an influential driver for manufacturers to engage in reverse logistics activities [414], [415].
- The EU "Right-to-Repair" measure implemented in 2021, as well as the globally increasing number of EPR policies, make it necessary for manufacturers to redesign their supply chain processes [416], [417], [418].
- The increasing number of single-use plastic bans, as well as the high value of the material (12-80bn USD) that is lost to the economy each year through the single-use of materials, are accelerating the shift towards reuse [419], [405], [420].

Challenges:

- For effective reverse logistics activities, standardized systems and collaboration across infrastructure and distribution networks are required to facilitate easy collection, recovery, and redistribution [406].
- The success of the reverse logistics business model is highly dependent on user motivation. This is because products offering reverse logistics require high user effort in order to return the products and are dependent on the wide acceptance from the society to use reprocessed goods [405].
- Reverse logistic services are defined by a high degree of uncertainty which makes operating such a service challenging. As reverse logistics occur in response to an action by a customer or supply chain actor, it is extremely difficult for a company to predict or plan for it [414].

Impact on the Future of Waste Management:

The shift from linear to reverse logistics provides companies with various options to better conserve used materials and therefore defer them from landfill or incineration. Through establishing their own collection processes for reuse, refurbishment, and recovery, producers are taking responsibility for the waste generated through the usage of their products. This minimizes their environmental impact and relieves the waste management industry. Moving from single-use to reuse also enables significant reductions in GHG emissions and other negative externalities generated during the production and transportation of new products [405]. Reverse logistics, therefore, follow the waste hierarchy's top levels of priority: reuse [374].

VALUE-FROM-WASTE

Giving Used Products and Materials a "Second Life"

Today's waste is tomorrow's resource: Even though the concept of second-hand clothing has been around for centuries, products that are created from waste materials are currently experiencing a new rise in global consumer demand [422]. The view of waste is changing from a negative drain on company resources to an opportunity to add value: Companies generate new revenue by selling products whose materials were originally labeled as worthless. Corporates and startups are engaging in this trend through means of upcycling, reuse, refurbishment, or the use of recycled materials [423], [424], [425], [426], [427], [428], [429]. While OEMs often reprocess materials they obtain back from their products, there is also a rise in third-party operators that are sourcing waste from other industries, like old truck tarps or fishing nets [431]. Giving waste a new life as a resource is explored from food production to concrete manufacturing, furniture, and electronics. However, it can be observed especially in the textile industry, which is due to its significant contribution to the emergence of MSW [423] and high customer involvement [433].

Facts:

- A high number of well-known consumer brands pledge to create products that are made up to 100% from up-/recycled waste within the next five to ten years [434], [435], [436], [437], [438], [439].
- The second-hand fashion market had a market value of 27bn USD in 2020 [440].
- The global recycled textiles market size was valued at 5.6bn USD in 2019 [441].
- The overall value generated per kg of raw material consumed is increasing. In 2020, Organisation for Economic Co-operation and Development (OECD) countries generated around 50% more USD per kg of materials than in 2000 (from 1.7 USD per kg to 2.6 USD per kg, calculated based on GDP values) [442]. Ambitious governmental goals support this trend event further [443], [444].

Key Drivers:

- Resource scarcity and dire environmental consequences along virgin supply chains drive manufacturers to capture the value of waste materials and keep them in a closed loop [445], [446].
- Consumers' willingness to pay more for sustainable products is growing with every generation [447]: 75% of US Millennials are willing to pay more for an environmentally sustainable product, compared to 63% of Gen Z, 64% of Gen X, and 57% of Boomers [448], [449].
- There is currently a high residual value of waste left unused and therefore lost for the economy [450].
- Increasing the lifetime of products has a direct impact on CO2 savings. Analysis shows that an extended lifetime of electrical products by just a year will save the equivalent of 2.1m tons of CO2 annually [451].

Challenges:

- Products that are made of used or recycled materials often have to deal with the stigma of being perceived as low-quality. A change in consumer mentality and education about the quality of repurposed products is key [452].
- Recycled plastics are still more expensive than virgin plastics, putting significant price pressure on recycled material markets and possibly making their use economically unsustainable [453].
- The quality of the input material is highly dependent on the development of new collection, sorting, and recycling technologies [454].

Impact on the Future of Waste Management:

Instead of following the traditional, linear product lifecycle, extending the life of materials and products will play a significant role in transforming our economy towards full circularity. The rise of "Value-from-Waste" business models is minimizing the volume of discarded materials being sent to landfills and promoting a material recovery that is compatible with the growing resource demand. Increasing demand for secondary materials through the reuse of waste will further establish the economic incentive for different players in the waste management industry to invest in new technology and processes that improve the efficiency of recovering the value that is hidden in waste materials.

SUSTAINABILITY CERTIFICATIONS

Accreditations that Prove Products' Positive Impact on Waste Management

Governments around the globe are introducing new regulations on the environmental friendliness of products and enforcing existing ones [455]. In addition, customers show growing awareness regarding the environmental impact of the products they buy [456] and often look for guidelines on how to choose goods and make "green" and "ethical" purchases [457]. These drivers are nudging manufacturers to find ways to prove the sustainability of their products, services, and supply chains and demonstrate their commitment to good environmental practices. While certification may require manufacturing companies to adjust their products and processes, it presents an additional opportunity for manufacturers to increase their prices and sales of their products at the same time [463]. It is also beneficial for recyclers because the requirements posed by certifications increase the supply and demand of recyclates [472]. This has the potential to increase the revenue of recyclers while having a positive impact on waste treatment.

Facts:

- There are certifications available for the entire waste management value chain ranging from certifications that certify products that are easy to recycle to certifications that certify recyclers who are good at extracting a very high percentage of recyclable materials within products [458], [459], [460], [461], [462].
- One-third of respondents of a survey conducted in 2017 said that they consider ecolabels in their purchasing decisions
- [464].
- In the US, between 2013 and 2018, the number of products marketed as sustainable grew 5.6 times faster than products that were not [465].
- Ecolabel certification from the EU doubled the number of products certified with their licenses between 2016 and 2021 [466], [467].

Key Drivers:

- Customer demand for sustainable products is growing [468] which is encouraging companies to prove the recyclability and environmental friendliness of their products using certifications.
- In addition, consumers have a higher willingness to pay for sustainable/recycled products. A survey done with USi and European customers showed that about 80% of customers are willing to pay a 5% premium and about 18% of the customers are willing to pay a 20% premium for green products ranging from electronics to furniture [463].

Challenges:

- Different certifications certify only specific properties of the product [470]. This makes it hard for customers to understand the validity of the different certifications and identify greenwashing. A survey done with Australian consumers in January 2021 reported that about 60% of customers say that it is difficult for them to make environmental choices because labeling is often unclear and confusing to them [473].
- Certifications often impose rigorous requirements upon a product which can stifle innovation [471].

Impact on the Future of Waste Management:

A growing number of certified products ultimately reduces the amount of waste that we as a civilization produce while increasing the revenue of all businesses involved across the value chain from manufacturers of products to the recyclers [463], [472]. This is made possible through two sub-trends that arise out of a steady increase in certified products over the last years. One is that an increase in certification is increasing the number of recycle-friendly products [466] and thus making it possible to recover a higher percentage of recyclates from waste. Another is that certifications often require products to incorporate at least a given percentage of recyclates into their products which increases the demand and price of recyclates [472].

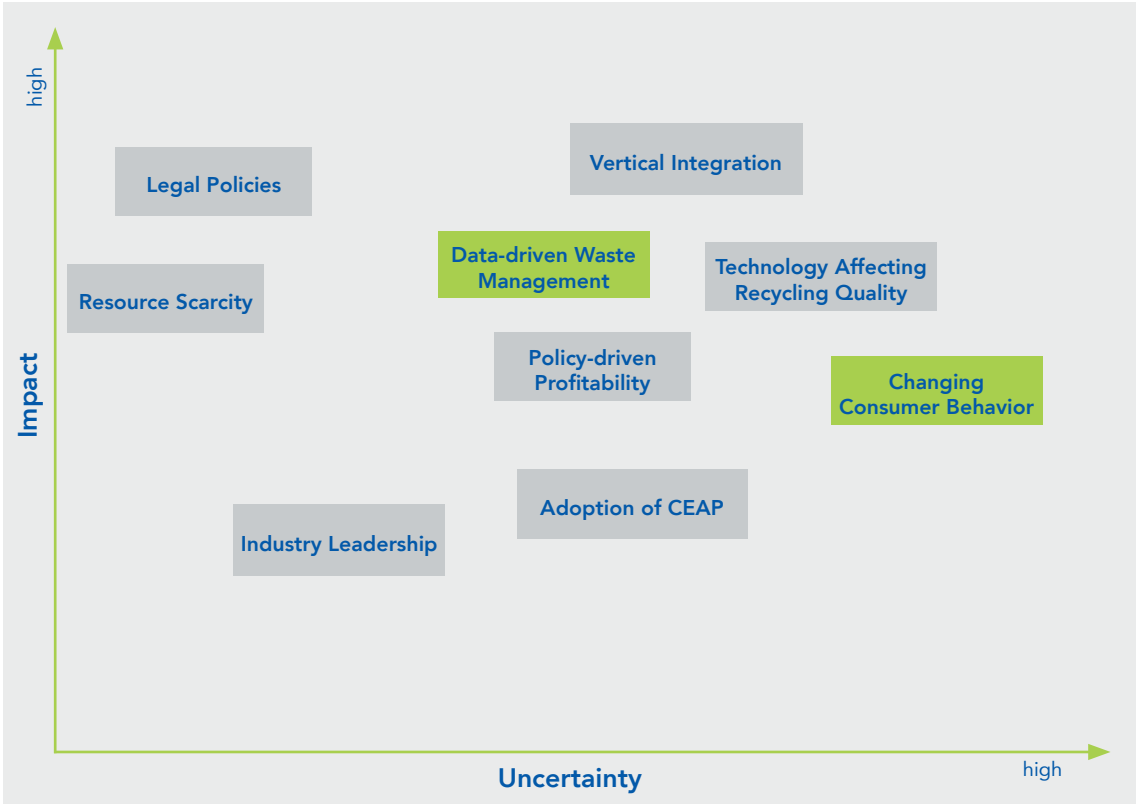
SCENARIOS

The following chapter describes four scenarios of different futures. The scenarios are plausible, relevant, challenging, consistent, and recognizable from the present and near future signals. All of the scenarios are equally plausible and derived from two identified key drivers. They present far-reaching visions of how the future of waste management might look like in 2041. Personal narratives tell stories of ordinary days in 2041 to allow an in-depth look into the future. Finally, identified signposts indicate the progress towards each scenario. They emphasize possible paths from the present to each of the four scenarios.

DRIVER MATRIX

The Scenario Phase follows a structured approach to imagine how life could look like in 2041. Based on the research conducted in the Basic Phase, current challenges and drivers with high uncertainty and high impact on the development of the waste management industry were identified. The drivers, which are forces shaping the future of the industry, are modeled with bipolar extreme outcomes.

The driver matrix ranks the identified drivers according to their magnitude of potential impact and degree of uncertainty. Based on these dimensions we have selected two key drivers, highlighted with a green background. The two key drivers "Data-driven Waste Management" and "Changing Consumer Behavior" are described in detail on the following pages. Additionally, a short description of all other drivers with high uncertainty and high impact is provided. Finally, the subsequent scenario matrix describes the four outcomes resulting from the combination of the two key drivers.



KEY DRIVERS

Waste Footprint at the Core of Consumer Behavior

In this setting, waste management has undergone a shift towards a pro-environmental behavior, contributing to better waste sorting and ideally less waste in general. The consumer is equipped with sufficient knowledge about waste separation and conscious shopping. Consumers generally bring reusable utensils to reduce packaging waste, choose products with longer product life cycles, and avoid plastic in purchasing decisions. Furthermore, this behavior extends beyond the initial purchasing decisions and also includes using repair services for broken goods and boycotting companies that handle waste poorly. Sharing is common with infrequently used goods such as cars and vacation homes, which is facilitated by many sharing platforms.

← Changing Consumer Behavior →

The term consumer behavior describes the actions and decisions people make when they purchase goods and services for their consumption. Within the waste management context, people can make choices that are beneficial or detrimental regarding their waste footprint. Environmental knowledge, attitudes, and social norms are the most influential predictors of potential behavioral changes. For example, the strength of these factors influences whether the waste is already sorted by the consumer or a new item is preferred over a second-hand product. It is not just individuals contributing to changing consumer behavior, but also private organizations, educational institutions, and governments that have an impact on this driver.

Consumer Behavior Without Considering Waste

In this outcome which lacks waste consciousness, consumers are not aiming to implement 3R efforts. Consumption is not focused on long-lasting products and packaging-free goods but rather on convenience, low prices, and habit preservation. There is a "to-go" culture in the society where disposable tableware is used every day, and items are thrown away quickly when they break. As proper waste sorting requires conscious effort, consumers will not attempt to do so in this setting. It is considered standard practice to litter since correct waste disposal is not considered to be a civic duty. Due to the low consumer demand for environmental protection, businesses have abandoned all pro-environmental efforts.

Low Usage of Data

In this extreme outcome, WMS hardly use data. Sensors and tracking technologies barely exist throughout the waste value chain. Due to the lack of data, strict quantified regulations are hard to enforce and control. Nevertheless, politics tries to foster sustainable behavior by pushing reduce and reuse practices. A lack of transparency in the value chain makes it hard for the general public to gather information about the sustainability of products. This leads to uninformed purchasing decisions and frustration in the population. Furthermore, it reduces the potential for further efficiency improvement in sorting and recycling waste.

← Data in Waste Management →

Insights gained through data into waste streams have the potential to impact waste management directly. Legislative measures highly depend on the availability of data. Strict regulations can be enforced by measuring the actual compliance to them. Tracking waste also impacts the extent to which consumers can make informed choices about their waste footprint. Regarding technical optimization, data plays a crucial role in the efficiency of recycling and sorting technologies. In order to use data effectively, it needs to be collected, analyzed, and shared between different stakeholders in the waste management value chain.

Data-driven Waste Management

In this extreme outcome, waste management is highly optimized through data. Throughout the complete value chain, data is collected through sensors and used to increase transparency in waste management. This enables legal authorities to enforce and track recycling and waste regulations effectively. Data-driven insights into consumer behavior help companies to forecast the demand for consumables to avoid disposal of non-consumed products. Smart infrastructure components like smart bins and autonomous waste trucks optimize waste bin placement and collection scheduling. The existence of data enables advanced sorting and recycling technologies. The collection, processing, and usage of data enable more efficient waste management through better planning, logistics, and waste collection. However, the importance of data privacy and protection also increases.

OTHER IMPORTANT DRIVERS

No Vertical Integration The value chain is distributed among small players with little collaboration.	← Vertical Integration →	**High Vertical Integration** Large players control several activities in the value chain.
Low Use of Primary Resources Circular economy conserves most primary resources.	← Resource Scarcity →	**Continuous Use of Primary Resources** Primary resources are continually depleted, becoming scarcer and more valuable.
Strong Political Involvement Politics regulate and set incentives.	← Legal Policies →	**Low Political Involvement** Politics hardly regulate and do not set incentives.
Adherence to CEAP The CEAP is the main guiding principle for waste management.	← CAEP Adoption →	**Disregard of CEAP** Waste management is not aligned with the CEAP.
No Downcycling The quality of recycled material can be preserved through technology.	← Technology Affecting Recycling Quality →	**Constant Downcycling** Technology is insufficient to preserve the quality of recycled materials.
Profitable Waste Management Policies enable profitable waste management.	← Policy-driven Profitability →	**Unprofitable Waste Management** Policies are inadequate to enable profitable waste management.
Businesses as Active Industry Drivers Rethinking business models towards profitability and sustainability.	← Industry Leadership →	**Businesses as Passive Actors** Businesses only adhere to legal obligations and consumer behavior.

SCENARIO MATRIX

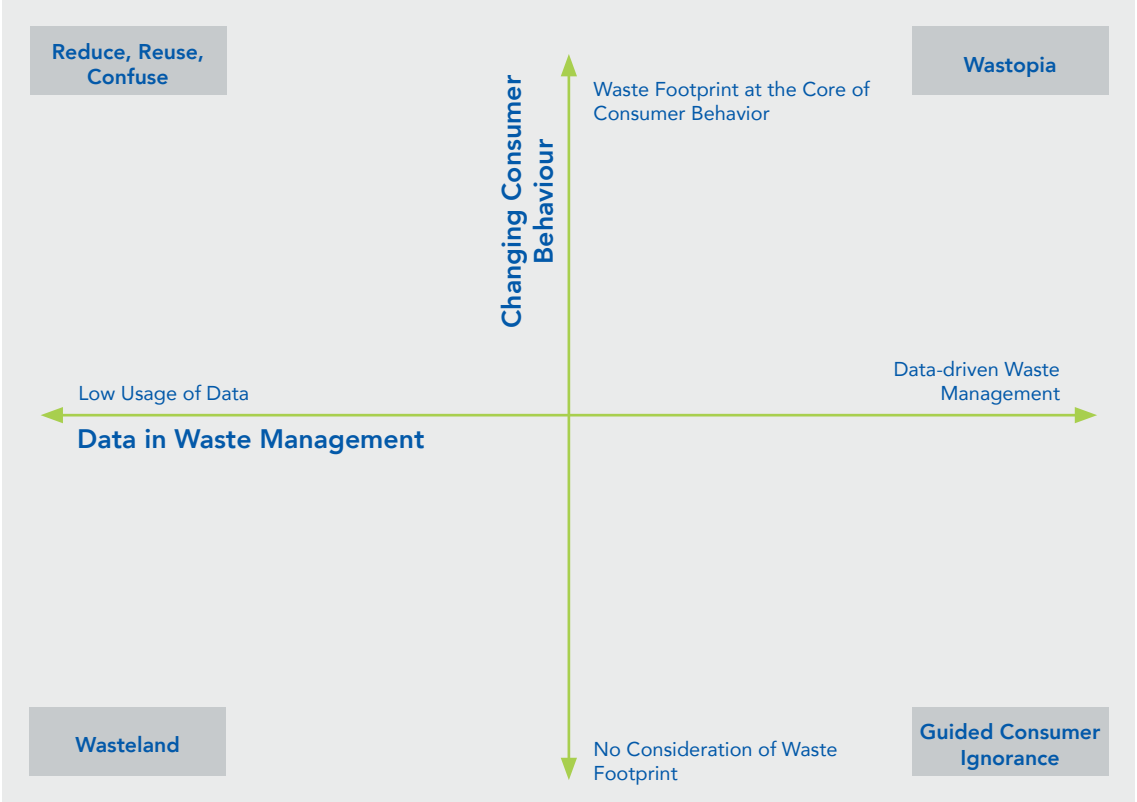
The two key drivers and their outcomes create a scenario matrix. Each key driver represents one of the axes, with the bipolar outcomes on the respective ends. All four scenarios are based on the extreme outcomes of the two key drivers. Other important drivers are also considered with plausible and consistent outcomes in each scenario.

"Wastopia": A future in which consumers are very conscious about sustainability and their waste footprint, fueled by complete data transparency across all waste management processes for the industry, as well as the individual.

"Guided Consumer Ignorance": In this scenario, consumers do not care about their waste output at all, but due to data-driven and profitable waste management, the businesses efficiently manage to compensate for the increased waste of the consumers.

"Wasteland": In this world, consumers live without considering their waste footprint, which, combined with the low usage of data in the waste management industry, leads to recycling processes becoming infeasible and extinct.

"Reduce, Reuse, Confuse": The consumers are very considerate of how their behavior affects their waste footprint, but decisions are aggravated by the lack of data in the waste management industry. This leads to frustrating inefficiencies for all stakeholders.



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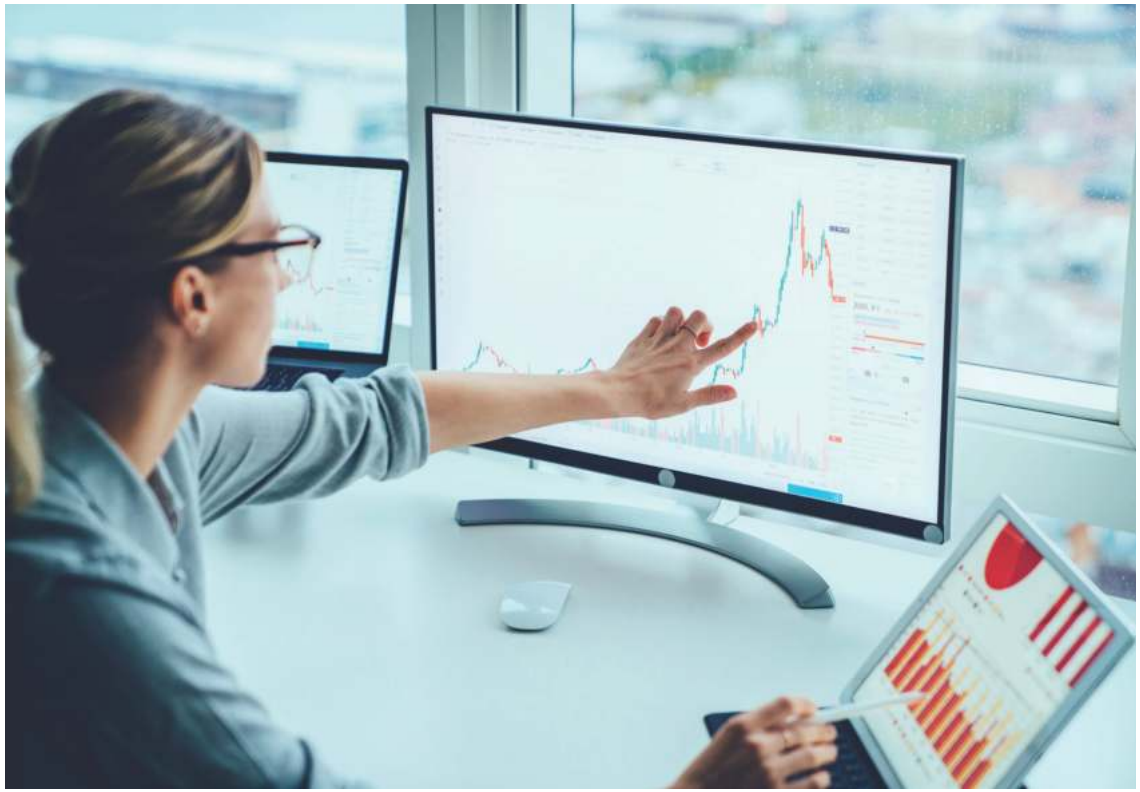
WASTOPIA

A Day in 2041, Where Citizens, Government, and Businesses Unite to Fight Waste Generation with Data-driven Techniques.



"Hurry up, Anna, otherwise you are going to be late for your first lesson!" says Paula while opening the bio-PET yogurt cup for her daughter. "Don't worry, mom, I still have an hour till the lesson starts. And we start with waste education anyhow. That's my favorite," responds the 10-year-old, looking at her smartwatch. "Happy kids…" Paula looks dreamily out of the window, "When I was your age, Fridays For Future only started, and we did not have such subjects at school. If you continue learning like this, you can teach your parents how to recycle properly!"

Anna nods proudly and heads to the smart bin with the yogurt cup in hand. After dumping the yogurt cup, the smart bin beeps, and the display reads: "Bio-PET package recognized. Fifth life cycle." Anna grabs her school bag and says goodbye to her mom and dad.

The trash bin's screen starts blinking red and shows that it is 95% full. Meanwhile, Paula gets a notification on her Wastify app, which she shows to her husband Tom: "Our bin is almost full. The autonomous waste truck will arrive in approximately 15 minutes." As sensor-based waste bins allow to track waste generation in different districts, an optimized route is calculated each time for the autonomous waste pick-up.

"This month, we are going to pay 10% more for the waste." says Paula looking at the billing section in the Wastify app. "No wonder," replies Tom defensively, "my parents stayed for a week, and we produced more waste than we usually do. I always try to make them aware of their waste production, but you know-how old-fashioned they are." She smiles, agreeing with her husband.

Paula gets ready to leave for work, puts on her headphones as well as her bicycle helmet, and kisses her husband goodbye. As Paula gets on her bicycle, she sees the waste truck's vacuum tube already connecting to the smart bin's exit port in front of the house. Now the extracted waste will be transported to the sorting facility. While riding, she turns on the latest episode of the "Sustainable today" podcast, a listeners' favorite across the nation. It starts with some positive foreign news: "India has finally banned all packages made of mixed materials!" Paula nods approvingly and rushes to work.

She enters the headquarters of her employer ClosedLoop, one of the few leading European recyclables companies nowadays. As Paula passes the entrance, she has a sudden flashback of her first day about 15 years ago. She recalls the joy and excitement of securing her dream job directly after finishing her Master in Data Science at the Technical University of Munich. Back then, the waste management industry was highly fragmented with predominantly local waste processors, overtaking only small steps in the value chain and thereby realizing rather low-profit margins. At that time, ClosedLoop was founded as a waste disposal subsidiary of the big grocery retailer TheDiscounter. But very soon, the company differentiated itself by integrating several steps across the value chain.

Paula's flashback gives her the shivers: It was the time when the waste management stakeholders did not collaborate much across the value chain, which made Paula struggle with missing and inaccurate data. But it all started to change on a snowy day in December 2027, when the German government announced to tighten national recycling quotas for all waste streams. This policy allowed the country to become a global front-runner in realizing the ambitious targets of the CEAP. As the German government

provided a nine-figure investment to set up the required infrastructure and implement suitable data-driven technology, Paula instantly recognized the opportunity for her future career and ClosedLoop. In the year 2041, waste management has become a highly reputable industry.

After passing the high-security entrance zone, including the facial recognition and fingerprint authentications, Paula hurries into her office. Twenty years ago, only NASA had such a powerful monitoring setup. The window facade reveals a panorama view over a joint waste sorting and recycling facility. Spanning an area the size of several football fields, the close collaboration of sensors, robots, and automated recycling machinery makes it possible to upcycle all existing waste types without human intervention. Engineers and data scientists enabled the factory to output secondary materials with product characteristics identical to primary materials five years ago. These upcycled materials allow minimizing the usage of primary raw materials across all ClosedLoop's packing manufacturing plants.

The facility alarm wakes Paula up from her daydreams. Still sitting in her chair, Paula asks her virtual personal assistant, "Hey Carl, what's the problem?" The voice coming from the speaker replies: "There seems to be an issue in the Label Remover section." Her screen turns on, zooming into the faulty processing step, and opens an interactive visualization. Paula built these dashboards some time ago to provide maximal transparency across ClosedLoop's waste value chain. These dashboards allow her to react much faster to processing problems. While trying to detect the root cause of the alarm, her eyes glance highly concentrated over several adjacent monitors, and her heart rate increases. With every second she does not identify the issue, the recycling quality decreases, resulting in costly fines for ClosedLoop. Suddenly one detail catches her eye: The throughput of yogurt packages shows a minor deviation compared to the norm. For the uneducated eye, it seems like nothing important, but Paula knows from experience how serious the problem of unremoved labels can play out.

As she finishes the thought, her virtual personal assistant Carl automatically sets up a high priority call with Diego, her colleague in the product design department. "Hi Diego, we have a big problem!" she greets him right away while the latest sales data pops up on her screen as their screens synchronize. They investigate recent packaging changes for yogurt cups introduced by the product designers of ClosedLoop. Thanks to an AI application that Paula has developed, the problem becomes visible: Because of the futuristic shape of the cup, the machine can only process it with 85% accuracy.

Diego sums up the problem: "The form of the yogurt packaging is not suited for our infrastructure. Therefore, our recycling rate dropped significantly. Based on the sales forecast, we need to prevent the product from going on sale next week. Can Carl send me the AI based recyclable 3D model right away?" While listening to her colleague, Paula already envisions the scandalous headlines coming in. She nervously agrees, and Diego reassures her that the updated product design will go live tomorrow.

Shortly before leaving the office, Carl speaks up: "Paula, excellent news coming from the European Cartel Office: ClosedLoop's municipal waste collection contract will be extended for a stunning additional six years." Before leaving the office, Paula asks him to calculate the positive effect of these news on the company's profit margin.

"How was your day, honey?" Tom greets Paula at the door. "Oh, I'm so tired", replies Paula, slowly taking off her shoes. "But it was a very productive day," she continues enthusiastically. "According to our estimations, ClosedLoop's profit margin will grow up to 25% - that's a 15 percentage point increase in just ten years." Tom congratulates her and says: "I also have some good news for you: I invited the Müllers for dinner on Friday." "Awesome!", exclaims Paula. "Then, we need to decide what we are going to cook so that we can preorder the ingredients from the zero-waste stores in our neighborhood right away."

Paula goes to the fridge and looks at the screen on its

door: It lists all the products contained and their respective expiry dates. Asparagus is blinking red as it should be eaten within three days. "Let's see what we can do with it…" ponders Paula while opening the Wastify app. It is integrated with all smart devices in the house and suggests meals based on the soon expiring ingredients in the fridge. "Oh, let's make seasonal potatoes and asparagus dinner - it's still spring, after all!"
After agreeing on tomorrow's dinner, Tom opens the Wastify app to accept the suggested grocery list and to select the preferred delivery time tomorrow after work. Right away, a new notification pops up on his phone, showing that their waste score improved by another 1%, reaching an excellent 87% score. When checking the details, he reconfirms that the score improved due to the high share of regional and seasonal ingredients from the local zero-waste stores. Those are always a safe choice to feel at ease with your purchase behavior. The Wastify app also allows users to share their scores voluntarily, so two years ago, Paula and Tom decided to make their waste score visible to their neighbors, the Müllers. "Look!" exclaims Paula, "Now we are ahead of Müllers - don't forget to make a joke about it on Friday."

Signposts

- QR codes on plastic products become mandatory - the EU enforces material tracking for better recycling.
- On the way to becoming the first smart city in Europe - Munich cleared the path to fully adopt smart bins.
- The green party has increased waste taxes for the coming year. German households have to pay an additional 5% for their municipal waste expenses on average.
- Many municipalities accept their citizens' waste scores to calculate individual waste collection fees - directly from the Wastify app.
- German government established the "SmartWaste Fund" with a 2bn EUR volume to accelerate companies' adoption towards tightened recycling quotas.
- A new Financial Times survey reveals that the ecological footprint of packaging is ranked as the most important purchasing criteria in Germany.
- Insolvency of Primark: How European legislators drive a former fast fashion pioneer out of business.
- WasteCo confirmed the data breach in their Wastify App: The waste disposal information of 5m households got public.
- Waste education becomes a mandatory part of the curriculum at school.
- Upcycling quotas realized: Germany leads the global ranking for Resource Productivity.

Annabell Schäfer, Aqib Ansari, Florian Wiethof, Leonie Wagner, Nikolaus Pinger. Claudius Seitz

REDUCE, REUSE, CONFUSE

Low Waste - Transparency Inhibits the Sustainability Efforts of Politics and Population

Beep Beep Beep! Bastian wakes up from the sound of the garbage truck passing by his apartment. "Will this ever change?", Bastian thinks to himself. He rolls over to check the time on his Smartpad: 5:30 a.m. Although it is convenient that the garbage trucks now pick up every waste type at every household, Bastian feels like he could still use another hour of good sleep. Reluctantly accepting that he is now awake, he heads to the kitchen. His roommate Flo is already there, preparing his breakfast - powdered oat milk and vitamins because it's "neither wasting time nor resources," as he always says.

Sitting down at the table, Bastian's Smartpad is recommending him a series of news articles. "Waste treatment remains the primary household expense of Germany," says the first article. The article claims that the increasing need for recycling complex products combined with missing data support is continuously increasing the costs of waste treatment. "What a waste of money," Bastian sighs. Last weekend he visited his sister in the neighboring federal state. Compared to the seven-bin system implemented in Munich, they are following a four-bin system. "If you don't have standards and information, you only confuse people and don't improve recycling." But Bastian cannot complain: During his studies, the highly manual efforts for waste treatment because of missing data gave him the opportunity for a well-paid job on the side.

After quickly finishing his breakfast, Bastian heads out for work. Almost at the door, his smart assistant reminds him to take along the deposit packaging to hand in later at the grocery store, where he pre-ordered his weekly demand for groceries earlier. He grabs the bag with the DeProsit logo feeling a small stitch in his heart since he cannot bring deposit packaging from other brands to the same supermarket.

Right in front of his apartment building, a ShareBike is waiting for him. Like every morning on workdays, it is automatically reserved for him, and, just like most people, he does not own the items for daily life but "co-owns" them – how the sharing community calls it. His smart assistant unlocks the bike, and he starts his ride to the office. He is listening to the weekly political podcast of the Green Party. 15 years ago, they enforced parts of the CEAP and the benefits from reducing and reusing have become apparent throughout industries. Right after its implementation, the clothing industry switched to mono-material shoes and accessories. But why is nobody, not even the Green Party, talking about the remaining lack of transparency in waste streams and the declining recycling quotas because of it?

Arriving at work, Bastian enters the office through an iris scan. After his two weeks of vacation, reality hits him hard. His intern Stefan is waiting right at the entrance: "Bastian, I have bad news: The data transparency efforts of the government have officially failed once again. Without data, we cannot expect any improvement in our current supplier situation. We still have to deal with continuously downcycled raw material and don't even have control or information on its actual composition."

Bastian has been working as a product expert at ReFresh for two years. ReFresh is a packaging producer specialized in mono-material PET packaging. The founder, Oscar Graden, is an active participant in the "Wednesdays Without Waste" movement. Some years ago, he saw great potential for making an impact through opening his own small business. Recently introduced subsidies for green businesses and the restrictions on mixed material products helped him identify his business idea. However, several people like Oscar took the chance to start their own sustainable businesses, leading to an increasingly fragmented manufacturing base. As so many businesses seem to do the same thing by now, it's hard for manufacturers like Oscar to negotiate with suppliers. Even though he would like to contribute to increasing transparency in recycling and waste streams, he simply cannot afford it.
With the disappointing news in his mind, Bastian approaches his boss, Oscar. The possibility of sourcing material from primary resources was already discussed a few weeks ago. Considering the limited availability, sourcing from primary resources is more expensive than recycled materials and likely to be banned soon. "The only option I see right now is that we follow the deposit approach and start closing our own loop. We should consider implementing reverse logistics to build our own assets", he proposes and leaves his boss to consider this option.

Bastian finally takes a lunch break. He scrolls through Twitter to update himself about the recent developments in the recycling industry: The growth of new organizations in the "sustainability" space is still ridiculously high. In the last six months, 12 new organizations have each amassed over 20 million Twitter followers. Some advocate for plastic to be eliminated, some just for PET. Sometimes chemical recycling is supported, sometimes not. Bastian does not get any smarter from the comments, either. Some of his friends are even active on contradicting pages at the same time. "Does no one have their own clear opinion anymore and is everyone just following loud opinion leaders?" The uncertainty in the population at least resembles the difficult decision-making process at ReFresh.

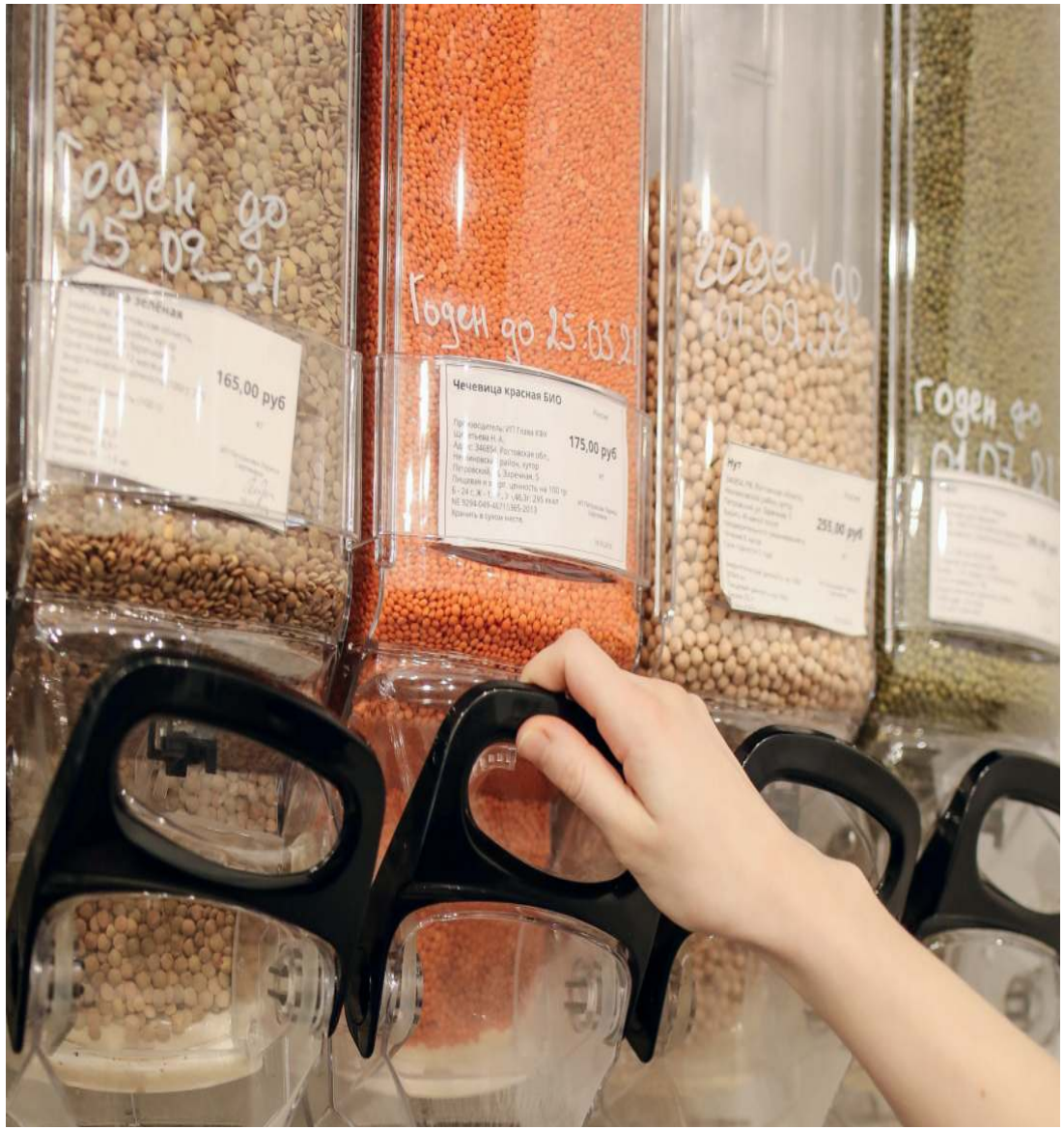
Before finishing his day of work, he has a final look at his notifications. As expected, the company canteen has food leftovers ready for pick-up. Without accurate data about the customers' consumption behavior, it is hard for the canteen to forecast the exact amount of food that will be eaten by customers. Bastian decides to pick up some leftovers to avoid the food being thrown away and leaves his workspace. On his way home, Bastian picks up his pre-ordered groceries and returns his containers at the deposit machine. The clerk hands him several plastic bags instead of the usual paper bags. "New decision by the management. Apparently, plastic is better than paper after all because it is reused more frequently and can perhaps be recycled better. Do you need anything else? Feel free to try more of our fully sustainable products." Bastian glances around the store: a sea of green packaging, labels, and ads. "You can filter by your favorite label in our app." Bastian pulls out his phone. The app offers more than 150 labels, hardly any of which he knows. As he scrolls, he comes across products offered and marketed by ReFresh: Awarded with 'Master Green 2040'. What does that even mean? What values do such labels add if there is no standardization or consistent regulations? Bastian asks the clerk in despair: "Whom should I trust now? What should I buy?" But the clerk is just as clueless: "What other options do the companies have? They are trying to get every label and every certificate possible. People demand sustainability. The companies try to satisfy them and compete."

After arriving back home Bastian meets his roommate in the kitchen. Flo has already unpacked a package holding the upgrade for their Smartpad and Smart Home Features. The two friends always enjoy it when they get tools and spare parts to upgrade their hardware to the latest generation. Since the legislation for the right-to-repair, many companies also implemented a right-to-upgrade subscription model for their products. As a subscriber, you can either get support in the store or do it yourselves at home. Bastian highly values this opportunity of not having to trade sustainability for top-edge technology but rather being able to have both. "It's a sense of individualism", he announces to Flo. "Speaking of individualism, I think it is time to redesign my shoes as well". The last time Bastian bought new shoes was years ago. Now he only shops in the well-equipped second-hand stores or

even prints them in his own 3D printer. Bastian puts his worn single-material sneakers into his grinder and chooses a new shoe design on his Smartpad, which notifies him that they should be printed in about 7 hours. Looking forward to his new shoes, the endless discussions of that day come to his mind - what a waste of time.

Signposts

- In 2025, the number of extreme weather phenomena has increased by 200% compared to the year 2010.
- "Zero-Waste" is the social media channel with the most traffic in 2027.
- Apple reacts to public pressure by introducing bi-yearly release cycles, reverse logistics, and right to repair.
- Second-hand arrives at the stock market with the initial public offering of Kleiderkreisel.
- Government Election 2029: The Green Party has achieved over 50% for the first time.
- Scientists still remain uncertain about the best recycling material. A new study proves that glass recycling is not effective.
- Recycling efficiency stagnates: Mechanical methods reach productivity plateau.
- New EU legislation enforces laws for "right to repair" and "product composition standards".
- EU study reveals that market fragmentation and high research and development (R&D) costs are the major roadblocks for data-driven waste solutions.



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WASTELAND

The Combination of Consumers Preferring Convenience over Sustainability and the Lack of Data Exchange between Companies lead to a Wasteful Future of Waste Management

7:00 a.m. The rain is pattering gently against the window as Andreas' alarm clock awakens him. He quickly switches it off and goes downstairs - it is time to make breakfast for his family. After taking out some bananas, apples, and oranges and unwrapping them from plastic, he starts cutting the fruit. Finally, the bowl is full. He sits down at the kitchen table made of rare rainforest wood to read the newspaper from Friday, September 13, 2041.

"Annalena Baerbock, former head of Green Party, resigns as chief executive officer (CEO) of Zara Germany" - Andreas has to read that headline twice to remember who Ms. Baerbock even is. The Green Party was disbanded after failing to get 5% of the vote to enter parliament in 2029 and 2033. Its leaders tried their luck in the corporate world but only enjoyed mediocre success. The industry was reluctant to become sustainable. The next page reads: "Bulgaria soon to be Europe's biggest landfill." Under the headline is a picture of huge mountains of garbage with some happy garbage collectors in the background. "At least they have some kind of work," Andreas murmurs as he gets up to leave the house and gets into his car. Andreas grins as he starts his car and hears the roar of the internal combustion engine.

On his way to the office, Andreas is thinking about the upcoming weekend when he stops at a red light on his way to the office. He looks around and spots a lone Friday for Future protester on the street corner with a sign that reads "The End is Near." As the traffic light changes, Andreas continues on his way to the office where he works as a logistics manager at one of the very last recycling plants in Munich.

After Andreas parks his car and enters the office, he is greeted by bad news from his secretary: "The new quarterly figures are in, Andreas, and we are making even more losses than last quarter. The board is not happy." "Well, ask the board how they would turn this company profitable in the face of policies that offer no support whatsoever and citizens who could not care less about sustainability," Andreas replies as he sits down in his chair.

Reluctantly, he begins a task he has been putting off all week: planning the new routes for trash delivery. Andreas picks up a pen and paper and begins sketching out the route plan for the upcoming months as the servers for the online route planning system have crashed as always. Frequently, he pulls out his phone to call countless customers, suppliers, and logistics partners to confirm their availability. Andreas grows increasingly annoyed. Again and again, he has to redefine routes or delivery days due to scheduling conflicts.

Andreas finishes another never-ending call about the route and glances at his watch. It is time for lunch. Quickly throwing all his notes into the trash, Andreas heads to the canteen. On the way, he sends a quick text to his wife: "When is Lisa done?" He is still getting used to picking Lisa up from school after being moved to part-time. How could that even happen? He was loyal to his company for 15 years, and yet, he was collateral when the company was desperately cutting costs to keep afloat. His phone buzzes: "2:20 p.m."

Andreas gets in line, picking up his plastic tray and cutlery. All food looks delicious – he fills his plates to the maximum and plunges at one of the tables. "We were just waiting for you" –

his colleague Martin frees space at the table and leans closer: "So tell us – is it true that Procter & Gamble (P&G) returned all the recycled products and is planning to sue us?" Andreas shrugs his shoulders – the news travels fast in this company. "True, they complained that the quality of our recycled materials is absolute trash. But what could they expect? Not that we are getting any improvement in recycling technology any soon. The government has cut all the R&D funds since CEAP fell through in 2030." Andreas quickly finishes the soup and discards the rest of the food, rushing back to jump on another call with the sorting companies. Each of them is the size of a fly, yet they truly believe that they can dictate their rules since the consumers have stopped sorting the trash themselves.

2:00 p.m. Time to go. As soon as Andreas parks by Lisa's school, his daughter jumps in the front seat. "Dad! My phone just died. I swear, I did not drop it!" Lisa pulls out the phone and shows a black screen without any signs of life. "Not a big deal, right? I wanted a new one anyway. I was the only kid in school that had an old phone for longer than six months. Everyone was laughing at me even harder than at that lunatic Roger, whose parents make him patch his clothes. I've heard that his family used to offer repairing services, but now they are bankrupt. Imagine, they even tried to repair his phone once!"

Half-listening to her chattering, Andreas signs and nods. "We will get you a new one, sweetie." As Lisa picks out a new phone, Andreas watches an extensive line in another part of the store. Apple just released a new watch. All the teenagers were eager to get one, pushing each other to get in front like a pack of hungry animals. Waiting for Lisa, Andreas grabs an ice cream at a cafe with a giant polar bear on its logo. What a marketing campaign - Andreas was sure that all the children drag their parents to the store to ask about the polar bears that exist now only in textbooks. The salesgirl politely smiles and offers him a tiny complimentary cookie accurately packed in plastic to preserve the fresh pistachio taste. On the way to his car, Andreas remembers that he promised his wife, Maria, to bring groceries for dinner, but decides to skip the task. They will order it from a 10-minute delivery company - he is not in the mood to go through twenty types of Greek yogurts in the store.

Back at home, Andreas notices that his driveway is once again littered with trash. Illegal trash pickers have scoured his garbage cans for valuable resources, spreading the trash everywhere. Furious, Andreas rings his neighbor's doorbell to ask if he has seen the trash pickers. His Bulgarian neighbor tries to calm Andreas down: "Don't worry, Andreas. It's

even worse in Bulgaria. Did you read the newspaper today? In Bulgaria, the garbage is simply everywhere because everyone in the EU sends their waste there to get rid of it. The EU has been talking about this issue for years, but what are companies supposed to do? You see for yourself how expensive and inefficient recycling is. No one in the EU has any idea about this problem or collects data about it."

Andreas nods and goes back into the house to relax in front of the TV. The news is again full of criticism of the German government as people are concerned about rising prices for electronic products. The prices of REE, which are needed for many electronic products, have risen to record highs – the ominous charts showing their climbing prices have appeared too many times on TV recently. He switches the channel just to find out that the chancellor is now backing asteroid mining as "the key to infinite resources." Andreas is about to continue jumping between the channels when he hears a journalist asking why companies should not be obliged to recycle more. The chancellor laughs: "In the past, bans and regulations on companies have never proven effective. Recycling would not only harm our economy but is also technically infeasible. Asteroid mining is the future."

Enough about resource scarcity, Andreas turns off the TV. He still vaguely remembers that twenty years ago, when he had just started working at the local recycling company, people were not talking about asteroid mining. Recycling and a circular economy were the future. Unfortunately, ever since CEAP fell through 11 years ago, there has been nothing left of that dream about a circular future. Already tired from the long day, Andreas reaches for his phone to set the alarm - but the screen is pitch black. Time to get a new one.

Signposts

- Following the failure of the European CEAP, the government cuts all subsidies and R&D funds for the recycling industry.
- Global waste trade agreement: Thailand is about to become the biggest importer of electronic, municipal, and construction waste produced in Europe.
- New strategy: Apple reduces release cycles for iPhones and Apple Watches to a mere three months.
- The end of sustainable consumption: Waste-per-capita in the EU reaches an all-time high for the fifth time in a row.
- Green startups about to be extinct – Green VC investments as low as in 1993.
- Convenience over sustainability: Consumers have made their decision. After the latest acquisition, the three biggest on-demand grocery delivery companies are now worth a combined 1tn USD.
- New NASA-backed mining startup successfully achieves to mine REE from their recent space expedition.
- Waste management ranks last in the recently released results of Deloitte's global digitization survey asking STEM graduates about their career aspirations.
- Data-driven waste management reaches rock bottom: Celonis officially abandons all ongoing projects with former waste management giant Veolia.
- AMP Robotics, the world's industry leader in AI-driven waste sorting technology, decides on a radical shift in the company's focus and becomes part of Tesla.

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GUIDED CONSUMER IGNORANCE

Data-Driven Waste Profitability Compensates Growing Consumerism

"Time to wake up, Lilly! Grandpa and grandma are going to be here in an hour," says Lilly's mum Frieda while gently stroking her hair. Ten-year-old Lilly lives with her parents in a loft apartment in the Munich suburbs.

She wakes up immediately with a big smile on her face: "Good morning, mommy! Yippie, I can't wait to go shopping with granny and gramps to buy my outfits for next month." But first, Lilly needs to get ready and have breakfast.

After getting dressed, she heads to the kitchen, where her father, Ferdinand, has already prepared a family breakfast. Lilly's eyes are sparkling as she sees that their new customized trial cereals are on the table for her to try out. She opens all of the plastic packages and puts a few spoons of each in her bowl. After deciding which flavor she likes most, she tops up her bowl and leaves the rest of the packages on the table without giving it a second thought.

Yesterday, Lilly ordered a new hoverboard on her tablet, as her old one broke while playing with it at school last week. She cannot wait for it to arrive, since the delivery company has promised that it will be produced and delivered to her today. Luckily, she goes shopping today anyway, so the time until the new hoverboard arrives will fly by. While sipping his coffee Ferdinand mumbles: "I don't understand why they want to go out shopping; it is a lot more comfortable just to order customized clothes online." Frieda smiles at her husband and explains: "Well, granny and gramps prefer to go out shopping in real stores, just like they did in the good old times."

The whole family swipes all opened packages with the leftovers from the breakfast table. Without separating anything, Ferdinand throws them in their sensor-based smart bin in the kitchen. After closing the lid, a message pops up on his smartwatch saying, "Nestle says thank you for disposal!" informing him that Nestle, who is the responsible company for the product, will take care of the proper recycling of the materials to contribute to the circular economy. Annoyed by the notification, Ferdinand wipes the message from his smartwatch.

When the doorbell finally rings, Lilly rushes to her dad's smartphone and presses the "unlock the door" button. She runs towards the hallway and opens the door in a hurry. Max and Katharina stand in front of the house and look excited to pick up their granddaughter for their day together. Lilly puts on her shoes and sprints outside to hug her grandparents. Then she suddenly acknowledges the movement of a big vehicle from the side of her eye. Lilly turns around in awe to see a fully autonomous garbage truck operated by Lidl roaming down the street: "Granny, granny, look at that!" The vehicle stops at every house and sucks all the waste from underground storage containers into its back while also collecting data about the types of waste the house has produced.

Lilly, Max, and Katharina walk to the metro station right next to the house. When entering the elevator to the platform, a photoelectric sensor scans their smartwatches and registers their ride at the Münchner Verkehrsgesellschaft (MVG) database. This way, all public transport rides are billed at the end of the year, and the MVG can optimize the train schedule accordingly.

"Which store do you want to go to first?" asks Max, Lilly's grandpa. "Primark!" Lilly shouts. "I want to get the same sweater I bought there last month. Mom threw it away two days ago because I accidentally spilled my bubble tea on it. But this time, I want it in white, pink, and yellow."

At Primark, Lilly is in paradise. She packs the shopping cart so full, it is almost too heavy for her to push. "When I was a young girl, they still had dressing rooms where you could at least try everything on once before taking it home and eventually returning it if it does not fit.," complains Katharina. She shakes her head, but fortunately for Lilly, she goes ahead and pays for everything. As clothes are really cheap, it is not a great

expense for Katharina, and in return, she gets a big smile from her granddaughter.
When they are about to leave the store, Lilly sees a big machine next to the exit. "Gramps, what is this weird robot doing here? "I'm sure you have heard of recycling Lilly. This machine helps the store clerks to sort all the old clothes that are broken perfectly, or customers do not want anymore. Afterward, it is all sent to a big recycling plant owned by Primark in the North of Germany. Because the machine analyzes the sorted waste so well, Primark can make new clothes out of it and sell them to you. Apparently, you can track your clothes' history via the QR code on the price tag, but no one ever checks it." Lilly nods and wonders why her parents never told her about that.
When they step out of Primark, they pass by a homeless man on the street. Lilly reads his sign: "I'm hungry! Food? Money? Plastic?" Lilly feels sorry for him, and while her grandparents tell her to keep walking, she regrets having thrown away the empty Haribo packaging she had in her jacket pockets until yesterday. "If someone had told me 20 years ago that plastic would one day be so valuable, I would have kept all my used yogurt cups," mumbles Max softly.

Lilly is a big fan of ice cream, which of course, cannot be skipped on such a great and sunny day with her grandparents. After she has finished her two scoops of Elderberry-Chocolate flavor, she throws the empty cup into a bin in the park. For it to open, Katharina scans her smartwatch again. That way, the municipality of Munich knows who threw away which kind of waste and can provide the best infrastructure. After hearing a short rumbling in the bin, grandma looks at her smartphone happily: "1.42 EUR deposit, that's 40 cents more than three years ago. The value of plastic really is skyrocketing currently." Lilly doesn't understand what this means exactly, but she is still happy with the ice cream in her tummy.
After a long and exhausting day, Lilly's grandparents stay at the family's house for dinner. They have ordered Indian food delivered from their favorite restaurant. "I'm so happy they are not taking part in this reusable packaging trend as all the other restaurants in the city." Lilly's dad states. "Apparently, Munich wants only reusable delivery packaging to be used until the end of the year. I'm not looking forward to being forced to send the plates and cups back, but I guess we do not have a choice."
Lilly's grandparents look at each other and shake their heads. When they were younger, they would have been happy to have so many restaurants being incentivized to reduce the waste they produce, but the current generations just care about their personal convenience.
Lilly's mum sits next to them at the table but appears to be a bit lost in thought as she checks the performance of her stock portfolio. When she sees that her shares in Umicore, Tomra, and Primark are each up more than 2% again, she grins contentedly and puts the smartphone away.
After saying goodbye to her grandparents, Lilly is about to go to bed. "Oh wait, Lilly! Your package arrived. Here you go!" says Frieda and hands Lilly the big package. Lilly tears its plastic packaging open, digs through the styrofoam, and finds her new hoverboard inside. Her mom forbids her to try it out immediately. Lilly is frustrated but quickly falls asleep, happy about her new clothes and dreaming of riding her new hoverboard. On its package, she read the word "Recycling" again and thinks of the machine at Primark. Lilly still is not entirely sure what it means and what it has to do with her hoverboard. She doesn't know that neither her new clothes nor her new hoverboard would exist without an interconnected recycling chain behind it.

Signposts

- Romania and Croatia are following the forerunner France in introducing EPR for furniture and textile branches.
- The German government introduces subsidies that make the recycling of 95% of the materials used profitable.
- The three biggest German waste management stakeholders own 70% of all German recycling and sorting facilities.
- Tönnies Lebensmittel GmbH & Co KG, one of Germany's largest food manufacturers, and Foodora, a food delivery service, enter the recyclables market.
- Lidl and Kaufland have extended their bottle deposit system to all recyclable plastic products from their product range.
- More than 60% of the European EEE manufacturers have implemented a deposit system for their devices, making significant improvements in recyclability.
- The biggest European waste management stakeholder introduces infrastructure investment plans, including fully automated sorting and recycling facilities and autonomous waste collection trucks.
- Zero-Waste Movement failed due to increased trust in governmental measures and established waste collection systems.
- Despite higher recycling rates, global waste production is still increasing by 5% per year. Total consumption continues to rise, increasing the scarcity of many natural resources, such as REE.

IDEATION

The following chapter describes five novel business models in the field of waste management. Each of the business models is described using the Osterwalder Business Model Canvas.

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CHA TAKA

Enabling Efficient Waste Collection and Transportation through Small-Scale Entrepreneurship in Sub-Saharan Africa

Waste picking in Sub-Saharan African countries like Kenya is still an unresolved challenge. Approximately 90% of all waste that is picked up is thrown in open landfills [474] with around 60% in an industry which is mostly operated by informal workers [475]. This insufficient waste infrastructure leads to problems regarding health, social security, and appropriate waste treatment.

Cha Taka is an abbreviation of the Swahili phrase for waste picking. This corresponds to Cha Taka's mission of tackling the waste problem by supporting organic waste collection in Sub-Saharan Africa. Cha Taka operates as the connector between collectors of organic waste and biogas facilities that value the offered material. The concrete solution consists of two major components: a task-optimized trailer and an app for operational support. The trailer can be leased by SSEs who can then use it for picking up pre-sorted organic waste from private households and commercial sights. Afterward, they bring the waste to biogas facilities which are paying them for the valuable material. The pick-up route and the best drop-off locations are optimized by the Cha Taka app to support the business operations and help the SSE to improve in their current earnings.

The solution provides the waste pickers with a secured formal income stream while having low entry barriers through the leasing model. At the same time, biogas facilities profit from having a guaranteed supplier network and higher material volumes. Finally, the local government and society benefit from improved infrastructure and decreased health hazards. Operating as the connector between stakeholders instead of employing enables Cha Taka to have a secured revenue stream while sharing the responsibility for the efficiency and business development with the waste pickers as affiliated SSE. The secure revenue stream consists of the monthly trailer leasing fee. The second revenue stream depends on the amount of waste the biogas facilities gather through Cha Taka's operations and, therefore, depends on the joint efforts of Cha Taka and the waste pickers.

Business Model

Key Partners

Funding Partners

- Development initiatives invested in infrastructure and environment projects, e.g., the Auslandshandelskammer (AHK) center for environment Nairobi or the Sub-Saharan Africa Regional Network for waste management
- Local governments for financial support and local knowledge

Operational Partners

- Biogas facilities as a key partner for monetizing on the collected organic waste material
- Service and maintenance partners for the trailers for

Key Activities

- R&D of the trailer and tool
- Production and maintenance
- Preserve key partner relationships
- Building up the ecosystem
- Negotiating material prices

Key Resources

- Local production facility
- Local market knowledge
- Knowledge in automotive and hydraulic presses
- Network towards biogas facilities

Value Proposition

Informal Waste Pickers

- Secured work and higher income
- Reduction of physical stress

Local Biogas Facilities

- Guaranteed and continuous supplier network
- Providing higher transparency
- Higher input material volume and quality to process

Local Governments

- Enabling infrastructure for the organic waste collection
- Improved hygiene and health conditions in cities
- Increase formal employment

Customer Relationships

Waste Pickers

- On-site support
- Digital operational support

Biogas Facilities

- Provide business data
- Identify new markets

Channels

- Waste Pickers: Website, Social Media, Branding of trailers
- Biogas Facilities: Non-Governmental Organization (NGO) meetups, Business networks

Customer Segments

Waste Pickers

- Self-employed entrepreneurs
- Workers with the goal to become more independent
- Workers wishing to improve their income and seeking a recurring revenue stream

Biogas Facilities

- Local or regional operators of biogas facilities
- Desire to increase their throughput and optimize their operations
- Expand their business and find new potential markets

Cost Structure

Initial Investment

- Development of waste modules
- Development of user application

Fixed Costs

- Employee costs
- Rent for office and factory
- Leasing of machines for manufacturing
- IT/cloud infrastructure

Variable Costs

- Material costs
- Customer support
- Business development

Revenue Streams

Constant Revenue Streams

- Leasing of waste truck modules
- Maintenance for SSE customers
- Organic percentage fee from biogas facilities

Eco-Social Costs

Societal Costs

- Reducing work for informal waste picking sector
- Traffic congestion in cities

Environmental Costs

- Relying on many trucks instead of one brings higher CO2 emissions
- Resources and emissions for truck production

Eco-Social Benefits

Societal Impact

- Standardization of waste management
- Reducing health risks
- Creating formal employment

Environmental Impact

- Reducing illegal dumpsites
- Reducing GHG emissions
- Encouraging recycling and sustainable energy sources

Value Proposition

Waste pickers: The main customers of Cha Taka are SSEs collecting organic waste for whom Cha Taka creates the most value. First, an introduction of the organic waste collection infrastructure represents new career opportunities for local residents. Thanks to the waste collection information and support that Cha Taka will provide to the waste pickers, the company enables secured and long-term work with stable and higher income opportunities. Furthermore, waste pickers will benefit from Cha Taka's trailers in terms of their physical health. If now informal waste pickers have to collect waste by hand and, thus, expose themselves to hard physical work, the organic waste collection by trailers will decrease the level of physical burden on a human's body. Finally, from an economic perspective, involving informal pickers in the coordinated organic waste collection process will decrease the entry barriers for them to become professional waste pickers and, thus, develop the waste collection sector in the region further.

Biogas facilities: With organic waste being one of the biggest untapped potentials in Sub-Saharan Africa, Cha Taka will provide local biogas facilities with a guaranteed supplier network delivering higher volumes of organic waste on a continuous basis. Furthermore, the waste collection infrastructure created by Cha Taka gives biogas facilities access to valuable and transparent data on organic waste materials. It will enable the facilities to forecast the amount of supply and track the data across different regions.

Local governments: Local authorities are one of the major stakeholders of Cha Taka's business model. They are particularly interested in creating the waste collection infrastructure that Cha Taka will provide. An efficient ecosystem for organic waste collection will help to solve an urgent problem of uncontrolled open waste disposal in city areas. This will significantly improve cities' hygiene levels and public health in general. From an economic point of view, Cha Taka will support local governments by creating new jobs and reducing the unemployment quotas in the Sub-Saharan region.

Customer Segments

Waste pickers: Currently, many unofficial daily workers make up for a significant fraction of the economic activities in African low/middle income countries, such as Kenya. Apart from self-employment by selling food, small-scale farming, and other informal activities, waste management guarantees an income basis for an increasing number of people as well. Waste pickers and waste sorters usually provide middlemen, scrap yard operators, recycling facilities or WtE facilities such as biogas producers with the processable waste they have found in open landfills in exchange for a small salary. Cha Taka's target customers show intrinsic motivation to become more self-determined and generate a recurring and increased income stream. They have also been working in the informal waste collection and sorting business for some time and are familiar with the rather opaque value chain of waste management in their respective regions.

Biogas facility operators: As organic waste accounts for most of the total waste generated, local biogas facilities provide the society on-site with an effective way to move organic waste out of the cities and generate value from it. With a higher amount of organic waste that can be transported over longer distances, the informal waste picker is able to skip the complex, opaque and unrewarding value chain of waste management, and become a registered supplier of local biogas facilities that ensures an increased throughput for the facility instead. Biogas facility operators working with Cha Taka are eager to scale up their business and find new potential markets. Eventually, this leads to a shift from treating organic waste in decentralized facilities at the household or community level to creating more efficient, centralized biogas facilities on a larger scale.

Customer Relationships

Waste pickers: Cha Taka empowers informal waste pickers and sorters to become SSE with a secured and recurring income stream. The goal is to understand the individual situation and the needs of waste pickers of the informal waste management sector by providing support and consultation throughout the leasing process of the Cha Taka trailer. Cha Taka will also provide personal support for maintenance, repairing, and route designing available on-demand. As Cha Taka contributes to the formalization of the waste management industry, a strong and trustful connection between the waste pickers and the biogas facilities will be required. Through transparent communication with both parties, Cha Taka acts as a facilitator of the relationships. ease the process of negotiating guaranteed prices for the collected organic waste, forming the basis for the waste pickers' recurring and secured salary.

Biogas facilities: Relationships between the biogas facilities and the empowered waste pickers will be based on personal interaction rather than on impersonal communication. This triangular relationship between the waste pickers, biogas facilities, and Cha Taka is key to the successful implementation of the concept. Regular technical support for the infrastructure that receives the fleet data of the trailers will, therefore, mostly be provided on-site and in-person as well. Helping biogas facilities gain valuable data and insights on organic waste materials and identify and build new markets will also be part of the personal interaction with Cha Taka. For both customer segments, Cha Taka follows a local employment strategy, as they are most qualified to grasp the needs and desires of the population. This will result in a significantly higher chance to implement a professional relationship with Cha Taka's stakeholders successfully.

Channels

Waste pickers: The large informal economy in Sub-Saharan Africa is also established in waste management. Unregistered workers generate small income daily by collecting and sorting waste from open landfills. To contribute to the formalization of the informal waste management sector and thus avoid social insecurity due to high dependency on opaque value chains, Cha Taka follows a broad and local communication strategy. Communication channels must be selected based on their probability of reaching as many informal waste pickers as possible. Cha Taka, therefore, aims to brand their own trailers, distribute posters and flyers in the cities, and place newspaper ads. In addition, digital channels such as a website or blogs are considered, all with the goal to create a call-to-action for people to engage in formal waste management activities by using Cha Taka's service.

Biogas facilities: As the existing recycling and biogas facilities in Kenya are rather small and not centralized, direct communication poses a large challenge. The channels mentioned above, such as the website, the posters, or the newspaper ads will also be used to reach local biogas facility operators who depend on organic waste to be transported to their facilities.

Cha Taka will also participate in NGO meetups, as institutions aiming for development aid in Sub-Saharan Africa have built up strong networks with local facilities, institutions, and people. Additionally, this channel opens opportunities to partner up with NGOs specialized in waste management and, specifically, biogas production on a larger scale. Gathering as much local knowledge as possible will be a crucial element of Cha Taka's entry strategy, which is why all communication channels will be used and extended constantly.

Key Activities

R&D of the Cha Taka trailer: As a hardware solution, the trailer needs some upfront R&D activities. R&D efforts will include the trailer modification, a potential waste press component, some sensors for analytics, and means to provide the sensor information to the users/partners. To master the trade-off between low cost and high-quality while having the local needs in mind it is important to have different stakeholders involved in the R&D process, such as local and domain experts. When the initial planning step is successfully completed, a production and maintenance ecosystem needs to be established. To provide quick maintenance, production facilities will be put in place close to the point of sale and usage. Furthermore, local stakeholders will be engaged in the process to improve the overall economic situation. As our solution depends on partners and customers it is important to put some upfront effort into building key partnerships with biogas facilities, local governments, and other partners. To ensure a sustainable business model, these partnerships need to be preserved and maintained.

Rather than focusing only on leasing the trailers, it is very important to provide an ecosystem. For that, the sensor data must be used for actionable insights, and the partnerships must be leveraged to create a sustainable ecosystem with low entry barriers. To create an organized working environment, it is important to negotiate standardized material prices and establish a market platform for biowaste to ensure demand is always there. From the waste picker's perspective, this ecosystem will ensure a secured revenue stream from the organic waste collection. Last but not least, Cha Taka will provide biogas facilities with valuable sensor data like waste amounts, allowing them to plan their efforts.

Key Resources

Cha Taka's mission is to improve waste management in Sub-Saharan Africa. To achieve this Cha Taka will operate as close as possible to the customers. Therefore, it is crucial to have a local production facility with qualified employees, which will improve the overall economic situation in the target city and improve the brand image of Cha Taka as it aims to become a recognized social employer. After including sensors in Cha Taka's "fleet" of waste pick-up trailers, a key future resource will be the data generated by them. The data will be crucial for negotiations with biogas facilities, further improve our product and give our customers guidance on how to make better use of our product, for instance by providing route planning tools. Generated data will also enable waste pickers to gain insights into their earnings during work, contributing to the continuous motivation of the SSEs. The knowledge about the local market and the opportunities of using our product will be crucial to attract customers and possibly convince people that are currently working in the informal sector to switch to a safer type of work in our system.

Especially for the upfront R&D activities, experts in automotive and hydraulic presses are needed to develop a trailer modification that fits all the specifications. The waste trailer design will mostly arise from extensive user research. The exact pain points, desires, and further inspiration will be condensed into a vehicle concept that allows Cha Taka to enter the market. A good quality hardware product sets the foundation for our operations and will help to attract customers. Especially the hydraulic press, combined with a low price, will help to set Cha Taka apart from the competition.

Key Partners

Funding partners: To enable an effective organic waste collection infrastructure in Sub-Saharan Africa, Cha Taka will need to work with funding partners aiming to increase the quality of life in this region. One of such potential collaborations is with AHK - the Delegation of German Industry and Commerce in Eastern Africa - as this organization also targets waste management problems in Kenya. Another promising partnership for Cha Taka will be with the Sub-Saharan Africa Regional Network for waste management, supported by the Climate & Clean Air Coalition and C40 Cities initiative. Climate & Clean Air Coalition and C40 Cities help Sub-Saharan cities to develop waste collection infrastructure. As Cha Taka's solution represents an important step towards the organic waste collection ecosystem in the region, such organizations might benefit from it as well and, thus, support the business. Finally, local governments are crucial stakeholders interested in developing an organic waste collection infrastructure in the region. Besides financial support, local governments are the source of knowledge about the regional peculiarities. More specifically, the first relevant partners for Cha Taka on the governmental side will be Nairobi City County, Kenyan Ministry of Health, and Ministry of Environment & Forestry.

Operational partners: To make the whole organic waste collection infrastructure work, Cha Taka will need to partner with local biogas facilities. Their participation is crucial for SSE collecting organic waste with Cha Taka's trailers, as the waste pickers get paid by biogas facilities for the materials they deliver. By providing benefits for biogas facilities through continuous supply and forecasting, Cha Taka will ensure demand for collected organic waste and establish and maintain the relationship between the waste pickers and biogas facilities. Finally, Cha Taka will collaborate with local service and maintenance partners for the trailers for on-demand support. This will allow Cha Taka to stay flexible and agile and focus on its core activities.

Revenue Streams

Cha Taka aims to provide an interface between waste collection services and biogas facility operators. Therefore, profit can be made on both sides, providing a constant revenue stream for the company, as waste pickers lease the equipment and biogas facilities pay a small fee for every kilogram of organic waste collected by the waste trailers.

Leasing of waste trailers: The baseline product for the whole Cha Taka operation is based on leasing the collection trailers to local SSEs for a monthly fee of 250 USD to make the business model attractive to a broad range of local customers. The amount can be adjusted depending on the local income of the region and increased when scaling the business model. This approach provides Cha Taka with a constant revenue stream from the SSE side, potentially hedged against a default risk with the help of local loan

partners. Additionally, the waste app provided free of charge for the SSE provides the company with valuable data for biogas facilities and business development.

Maintenance of trailers: To provide a secure and risk-free operation to the SSE, Cha Taka provides predictive and on-demand maintenance for the SSE, essentially insuring them against a loss of income due to a broken waste trailer. They can get a notification and are able to book a maintenance slot directly through the app, enabling Cha Taka to plan their maintenance resources more effectively.

Organic waste material fee: On the biogas facility side, the operators need to plan their intake to scale operations. Cha Taka provides a steady supply of organic waste, including the amount and weight of the material as valuable business data. For this service, Cha Taka charges the operators 3 USD per ton of waste. Initially, Cha Taka does not charge this fee to make it more attractive for biogas operators to build more facilities in the region. Still, with a higher market penetration, this fee will provide a constant revenue stream for the company.

Cost Structure

Initial investment costs: To start the Cha Taka ecosystem, an initial budget for the development of the waste trailer is required. Qualified automotive engineers are needed to develop a minimum viable product (MVP) and the first batch of production-ready waste trailers. Because these engineers are expected to have substantial knowledge and experience, salary will be a major cost factor. Additionally, it will take some upfront investment to start the company and set up a small factory in Kenya. An additional factor will be the development of the SSE mobile app to coordinate the waste collection operation. For this platform a small team of freelance software developers is needed which must be considered for the initial budget.

Fixed costs: Operating Cha Taka will have several fixed cost factors independent of the number of active customers. The factory space and the lease cost of the production machinery will be the primary cost driver, reducing the initial investment, but contributing to the recurring costs. Additionally, the IT infrastructure, primarily hosted in the cloud, will have a share in the fixed cost structure to control the production machinery, operate the app, and guarantee working IT for Cha Taka's overall operations. Furthermore, the company will continuously invest in R&D to improve the waste trailers and make the app platform more accessible to customers. Finally, the salary for administration staff, production workers and maintenance crew will contribute to the fixed costs.

Variable costs: The main variable costs arise from materials and parts for the waste trailer production, depending on the demand. Additionally, the capital required for business development contributes to the variable costs. As SSEs and biogas facility operators need to be approached and a business network is built, these marketing and sales costs will be a significant cost factor, especially when expanding operations to new cities or markets.

Eco-Social Costs

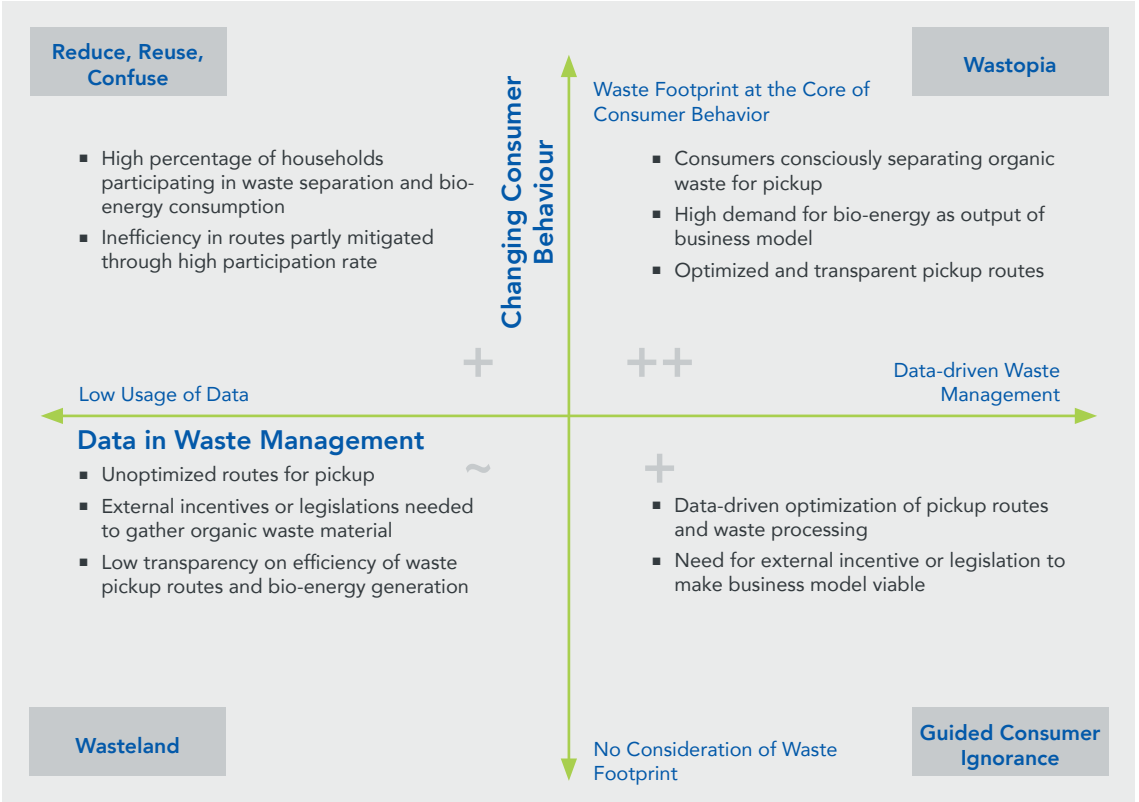
Societal costs: Cha Taka aims to tackle the waste collection problem in Kenya, which is currently unorganized and only partly served by the informal sector of day laborers. The Cha Taka business model could pose a risk to this part of the society, as they rely on waste collection and could not compete with a scalable company and their SSE partners. However, the informal sector mainly focuses on plastic waste and valuable materials and therefore has not shown

interest in organic waste with smaller margins for them.

Environmental costs: Relying on many private trucks and cars instead of centralizing on company-owned trucks brings higher overall CO2 emissions from the pick-up process and more bound materials. This is on the one hand caused by the higher number of involved vehicles, on the other hand also due to less control over the used engines and energy efficiency for the vehicles.

Eco-Social Benefits

Societal impact: Cha Taka aims to create eco-social benefits in mainly two ways: Employment and health. Since Cha Taka plans to change the whole value chain to developing countries, it will create jobs at different levels. Through the local production and maintenance, jobs will be created for skilled labor that either support in R&D, production, or maintenance. Further, the potential customers will benefit from the "purchase" by being enabled to work. It will be especially beneficial for uneducated or people working in the informal sector to work in waste management, since it has very low entry barriers (e.g., lease instead of buy). Regarding the health of the local inhabitants, Cha Taka can also provide benefits. As waste pick-up was handled unstructured before, organic waste was often stored close to the population and, therefore, transmitted infectious diseases. By providing a functional waste collection system, these risks can be mitigated, helping to reduce the pressure on the local healthcare system.
Environmental impact: The Cha Taka approach to building a functional waste collection service could also positively impact the local environment. Currently, society dumps a major amount of their organic waste near their houses or on illegal and uncontrolled waste sites, potentially harming the local wildlife. These dumpsites would disappear with the approach of Cha Taka, as the collection is easy and free of charge for the citizens. These dumpsites are also a negative climate option in terms of uncontrolled GHG emissions. The conversion to biogas could reduce these emissions significantly while also encouraging the production and usage of sustainable energy sources by utilizing biogas.



Scenario Fit

Wastopia: In a scenario of high consumer awareness and data-driven waste management, the Cha Taka business model could flourish. Consumers would separate their waste correctly, enabling drivers and biogas facilities to operate more efficiently, although overall waste production would potentially decrease due to consumer behavior, reducing the number of required trailers for a certain area. Consumers would engage the service more frequently, so charging them could be a viable business option in this scenario. The increase in technology and data reduces trailer and operating costs, lowering the entry barriers for potential customers. The data could also function as a key driver for expanding biogas facilities in previously undeveloped regions, further growing the area of operation for Cha Taka. Overall, the scenario offers several new options to expand and develop the Cha Taka business model without changing the underlying ideas of the company.

Reduce, Reuse, Confuse: Private consumers and commercial sights are highly effective in proper waste sorting. They actively reach out to the waste pickers for a pick-up on a regular basis and inform themselves about the proper waste sorting habits. For the waste pickers, predictive route planning is not possible due to a lack of data. However, through the high regional density of pick-up locations the business is still viable, though not optimized. The biogas facilities profit from frequent

high-quality input material, but cannot actively plan. The situation for all included stakeholders is beneficial, although not optimal, as waste collection is in demand, but operations are challenging. For Cha Taka this results in high numbers of leased trailers and good partnerships with biogas facilities, however with the downside of not being able to provide valuable data to the facilities, potentially decreasing the revenue of the company.

Wasteland: Due to a lack of available data in waste management, customers of Cha Taka refrain from unoptimized routes for their waste pick-up. To maximize the amount of waste they deliver to one of the decentralized biogas facilities, waste pickers mostly base their routing decisions on intuition and routine. As Cha Taka's service neither includes a smartphone for the pickers, nor sensors to connect the trailers with one another, different waste pickers often stop at the same locations to collect organic waste. This leads to many empty rides and, eventually, less income for every stakeholder involved. Facing the trend of urbanization in Sub-Saharan Africa, the amount of waste in urban areas is growing rapidly, causing serious health hazards for the population. However, governmental incentives and legislation are needed to collect organic waste since appropriate disposal is not a major concern for society. Cha Taka's business model can, therefore, only be viable if political support is ensured.

Guided Consumer Ignorance: Regarding consumer ignorance, Cha Taka can partly play a positive role. Private households do not have an interest in waste separation or changing their behavior. On the other hand, trailer operators are motivated to collect as much organic waste as possible, offering a balance point to consumer ignorance for collection. But the quality of organic waste is likely to decrease, as consumers do not separate their waste properly, influencing the prices of the biogas facilities paid for organic waste. A data-driven scenario is beneficial to Cha Taka regarding transparency of location and amount of waste, leading to a more dynamic routing of waste trailer operators, which makes the service more effective and profitable. This can be the foundation for building a functional waste collection service in Sub-Saharan Africa, which is especially useful in a scenario of increased waste production.

Challenges

- **Building local knowledge:** The assumptions regarding the business mechanisms and the waste management landscape, even though iterated with local experts, are currently strongly based on European views. It is crucial to understand underlying local dynamics and processes on both personal and governmental levels to ensure the functionality of the idea and create the desired value-add to the locals.
- **Chicken egg problem:** Our value proposition for the parties that we aim to connect – waste pickers and biogas facilities – is dependent on the respective market penetration of the other. To bridge this challenge, initial investments and a trustful, professional relationship must be established.
- **Legal formalities:** A significant fraction of the economic activities in Sub-Saharan Africa is attributable to the informal sector. Ensuring compliance of the waste pickers with legal formalities is of key importance for the overall local integration of Cha Taka, as local governments will be crucial partners of Cha Taka.

Outlook

Sub-Saharan Africa is a major and unexplored market for waste collection and treatment, offering a lot of potential. To successfully establish the Cha Taka business model, several different aspects need to be considered for future growth. First, a local team needs to be found and hired, as knowledge of the local market and social/legal stakeholders is essential for successful implementation. Regarding funding, local investors and VC can be considered, as well as NGOs and development aid to quickly establish a market. The company begins operations in Kenya, but can expand to the whole Sub-Saharan Africa region after gaining traction in the urban areas of Nairobi and other cities. The revenue can also be used to improve the quality and reduce the production cost, further lowering the entry barrier for local SSE. As Cha Taka relies on biogas facilities for the value chain, close cooperation for the expansion needs to be considered. Alternatively, it is also possible for Cha Taka to build biogas facilities on its own, based on the data collected from successful operations.with valuable insights into their sleeping patterns and ways to improve their sleep quality besides noise-canceling. At this point, Sleepi is designed as a one-time purchase, but with additional features such as sleep analysis could also develop towards a smart pillow on a subscription basis. In the future, the algorithm could further be trained to effectively cancel out other noises in the sleep environment besides snoring sounds and thus offer additional value to people living in noisy urban areas. Furthermore, Sleepi may provide personalized pillows with further adjustable neck support, height, and shapes, and foster collaborations with corporate partners such as hospitals, sleep clinics, and insurances.

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CHUTEOUT

The Smartest and Most Convenient Way to Manage Waste in Multi-Storey Buildings

The global trends towards urbanization and population growth lead to an increase in waste production, especially in high-rise buildings. It is challenging to effectively manage waste inside these buildings. The system needs to be simple to install, clean, and maintain. Consumers rarely take time to sort or recycle their household waste, so it needs to be as convenient as possible for them to improve pre-sorting quality as well. A building-level smart system leveraging the information of waste streams at the source, including the consumer's convenience, is missing on the market.

Chuteout fulfills the need for such a solution. It maximizes consumer convenience to discard waste, increases pre-sorting quality, and tracks waste creation and composition. Each flat in a building is connected to a single central chute by a dedicated bin. The type of waste is selected on the tablet above the bin. The weight is tracked in the containers in the basement and sorted by a simple mechanical system. This allows tracking the waste production per waste type and household, and potentially trace back wrong sorting behavior. Having this information enables concepts such as pay-as-you-throw to decrease overall waste volumes.

The central chute contains automatic ventilation and cleaning to minimize the need for maintenance. Decreasing waste and increasing the sustainability of the building is an important selling point for higher rents. The collected data is highly valuable for private and public waste management companies and can be accessed via an API. Paired with our in-house software development, our data supports further improving logistics, sorting, and recycling in waste management. Also, the decrease in total waste and better pre-sorting lead to a lower load on waste management overall. The architects and building owners receive an innovative way to manage waste.

With its own production, installation, and maintenance service, all branded "Made in Germany", Chuteout is delivering a high-quality and robust solution. Its local correspondents in every partnering country understand the requirements of each region and build strong relationships with customers and partners. Chuteout will lead the path into a future of digitized waste management.

Business Model

Key Partners

Local Architects

- Well connected to housing companies
- Present the chutes to prospective projects

Waste Management Services

- Close contact to lobby for integration of data
- Growth Stage: force WMS to use data and build on increased digitization of the sector
- On-demand local support

Maintenance

- Early Stage: local subcontractors for maintenance work
- Growth Stage: subsidiaries

Key Activities

- Product Development (R&D, implementation and testing, production and shipping)
- Customer Acquisition Through Champions
- Installation and operation, maintenance and data processing

Key Resources

- Recycled metals for chutes
- Patents
- Sensors to collect data
- Software developers and Engineers
- Installation team
- Referral network

Value Proposition

Maximum Convenience for Consumers

- Convenient and hygienic disposal and separation of waste

Effect on Waste Management

- Provision of disposal data
- Higher quality of pre-sorting from private households
- Reduction of plastic bags and bins

Benefits for Architects & Owners

- Tracking of waste creation and associated costs for disposal
- Enabling pay-as-you-throw
- Fast and reliable installation through modular design

Customer Relationships

- Housing Companies: Long-term collaboration on projects
- Architects: Deep, long-term relationship to win architects as "Champions"
- Waste Management Companies: provision of high-quality longitudinal data

Channels

- Cold Channels: Website, posters, cold calling
- Warm Channels: Network of big architectural offices, Architectural and real estate trade fairs, Word of mouth among housing companies and architects

Customer Segments

End Users

- Inhabitants of 10+ storey buildings in cities with sufficient waste infrastructure
- Focus on top 30 cities with the fastest growing skyline
- Potential extension to multi-storey commercial buildings

Customers

- Housing companies building 10+ storey houses
- Waste management companies

Cost Structure

Direct Costs

- R&D for hardware and software
- Raw material, staff, machines, and factory for chutes
- External parts like sensors
- Production of spare parts
- Staff or subcontracts for installation and maintenance

Indirect Costs

- Administrative overhead
- Patents
- Operation of software services

Revenue Streams

One-off Revenue Streams

- Chute upgrades and spare part sale
- Contract price for chute and services

Recurring Revenue Streams

- Providing data to waste management companies and municipalities
- Maintenance contracts with housing companies

Eco-Social Costs

Production and Installation

- Non-renewable production resources
- Air travel of experts and shipment of parts
- Poor conditions for workers in fast-developing countries

Operation

- Non-renewable sources of electricity, chemicals for regular cleaning

Eco-Social Benefits

Ecological Benefits

- Improved waste pre-sorting
- Reduction of waste volumes through pay-as-you-throw
- Improved hygiene

Benefits for Customers and Society

- Transparency of waste production through data
- Creation of maintenance jobs

Value Proposition

The value of Chuteout extends to consumers, housing companies, and the waste management system and infrastructure in general.

Consumers: Chuteout maximizes the convenience for consumers to dispose of and sort their household waste in various ways. As with other conventional waste chute systems, consumers can directly dispose of their waste in the building without taking it out. Opposed to other waste chute systems, however, Chuteout's system extends to each individual housing unit rather than only providing a single garbage chute per floor, making it even easier to dispose of waste. This design also eliminates the need for a kitchen bin to collect waste before disposal. By doing so, it reduces the required touchpoints with waste, increases hygiene, and minimizes the exposure to unpleasant smells. Additionally, Chuteout offers a modern display interface to select the type of waste for separating it. The system enables consumers to sort waste in a convenient way without having to place multiple bins in their flat to do so.

Housing companies and architects: The sensor-equipped Chuteout system enables building owners to track the creation and composition of waste per building and apartment. This data can be utilized to implement pay-as-you-throw schemes. These generally lead to a significant reduction in total waste volumes and, thus, improve the overall environmental footprint of buildings. Architects appreciate the robust, but modern design of the slide and the fast and reliable installation made possible by the modular approach of the system.

Overall waste management: The easy waste separation solution of the Chuteout system incentivizes consumers to sort their waste better. This results in a higher quality of pre-sorted waste from households and positively impacts recycling overall. The collected consumption data and information about the fill level of the collection containers can be provided to WMS to improve their operations, sorting, and truck routing.

Customer Segments

Chuteout understands its customer segment as those who use the chute, as customers of its service, and as those who pay for the chute.

End users: As waste chutes make more economic sense in multi-storey buildings, Chuteout has decided to focus on residents of buildings with at least ten stories. In addition, expansion is limited to cities with sufficiently developed waste collection infrastructure, as improved recycling, less waste, and integrated waste management data must be the focus. At launch, Chuteout is primarily focusing on the 30 cities with the fastest growing skylines, such as Shenzhen, Dubai, Mumbai, or New York City.

Customers: Chuteout sees housing companies as paying stakeholders and therefore customers. As with users, Chuteout has decided to focus on customers who are constructing new buildings of at least ten stories in the 30 cities with the fastest growing skylines. There is also the possibility of expanding the user base to include commercial buildings, such as hospitals, offices and shopping malls. However, due to the pay-as-you-throw option and the individual household connection as a unique selling point, commercial buildings would be more likely to benefit from important features, such as convenient waste treatment and

Customer Relationships

Housing companies: Chuteout seeks long-term relationships with all project-partner housing companies due to the inherently long-term nature of the Chuteout product. As part of the warranty and maintenance agreement, housing owners can access a customer service hotline for all questions regarding the operation and maintenance of the chute. Queries that require immediate or more dedicated action, such as the occurrence of severe technical issues, the ordering of spare parts, or the planning of future projects, are handled by dedicated sales and support staff.
Besides the relationship with the housing companies, Chuteout recognizes the architects it works with as powerful

intermediaries with considerable influence on the decisions of housing companies. Thus, Chuteout invests in establishing deep, long-term relationships with architectural offices and individual architects. Architects are provided with dedicated personal assistance on the product side to convince them of the Chuteout value-add, eliminate doubts, and win them as "Champions" for Chuteout products. To obtain relevant product-specific information, architects have access to a comprehensive library of product documents and case studies.

Waste management companies: Chuteout acts as a reliable partner and provider of high-quality data for waste management companies. It strives to cooperate and establish long-term relationships with waste collection, waste sorting, and recycling companies to ensure that the data collected by Chuteout systems is leveraged to its full potential. New data points and better-to-use data formats are identified through regular communication with data specialists from the customer side. Customers also have access to the Chuteout data documentation to obtain detailed information about specific data points, analyses, and collection methods.

Channels

Cold channels: In order to win real estate companies as new customers, Chuteout has to convince architects of its superior value. One of several first touchpoints with architects is the informative and transparent website, which openly provides all relevant technical details and cost information. Chuteout works with SEO optimization and Google Ads to accelerate its popularity. Visualizations, like videos and graphics, accompany the website to explain the chute system and the role of data in waste management, which allows Chuteout to demonstrate the competitive advantage. Additional advertisements, like posters, will be placed at current construction sites, since architects spend most of their time there. Lastly, Chuteout's sales team will cold call various architectural offices in an early stage, as it is crucial to close a pilot project.

Warm channels: As personal networks and word of mouth are the most prevalent ways to expand the customer base in the construction industry, Chuteout opens three local offices in its main urbanization hubs New York City, Shenzhen, and Abu Dhabi. The local offices can build up strong connections with important architectural offices to build up a global referral network. Furthermore, the worldwide distribution of staff enables participation in architectural and real estate fairs or events to gain new connections and strengthen existing ones. The strong personal network will later result in mouth-to-mouth advertising within the industry during the growth stage. During this phase, local customer support becomes crucial to ensure no questions regarding the chute system and data service remain unanswered, and problems can be solved quickly.

Key Activities

Product development: The general structure of Chuteout can be built in a similar way to current waste chutes in multi-storey buildings. However, R&D is required to ensure smooth connection of each individual household, as the electric piston system is the first of its kind in the industry. Therefore, iterative testing and prototype implementation are required to prepare for market launch. Finally, Chuteout manufactures and ships the chute modules from its manufacturing facility.

Installation: In the early stages of Chuteout's expansion, internal installation teams are dispatched to support and coordinate external construction workers at the chute's location. Once a growth stage is reached, Chuteout's existing local network is leveraged to establish subsidiaries in regions that have the potential for further growth in chute installations.

Maintenance: All buildings with an integrated Chuteout system will be covered by a five-year warranty. In the initial phase, Chuteout will use local subcontractors for maintenance work. Once the growth phase is reached, subsidiaries will be established in regions with multiple chutes to generate recurring revenue from maintenance.
Data collection and processing: Sensors are used to collect relevant disposal information such as weight, date, and time of disposal. This data is analyzed to set up a pay-as-you-throw system for residents to incentivize recycling behavior. Finally, Chuteout is advocating for increased digital infrastructure and data use in WMS.

Customer acquisition through champions: To establish close relationships with local architects, Chuteout will invest resources in building and maintaining strong relationships with local champions, namely architects. This will include networking with local architectural practices, for example at relevant events and trade shows. The main objective is to convince architects of Chuteout's high level of convenience, sustainability, and functionality. This can be done by providing high-quality content that architects can use to inform and promote Chuteout to housing companies.

Key Resources

High-quality hardware: As Chuteout offers a high-end hardware product with sophisticated technology, it is crucial to source the components from the best high-quality suppliers. The mission of Chuteout is to actively contribute to a more sustainable environment which starts with using as much recyclable material as possible to build durable chutes. The modular design and technical components of the chute system have to be protected by patents to ensure future competitiveness. As Chuteout offers data services next to

the chute infrastructure, they require sensors to enable data collection.

User data: The waste data of the chute users constitutes the crucial basis for leveraging Chuteout's system and offering the data service to landlords and in later stages to waste management companies.

Human resources: Chuteout relies on software developers to build up an API to extract the waste data of the chutes. This enables Chuteout to become a data service provider for the waste management industry. Next to that, Chuteout needs engineers to develop and construct the waste chute modules. As the chutes are installed on-site in close consultation with the architect, Chuteout employees are required at the locations to coordinate locally subcontracted construction workers. At a later stage, Chuteout plans to have globally distributed subsidiaries to conduct the installation themselves.

Strong relationships: As the construction industry relies on strong ties and word of mouth, it is crucial to establish and maintain a strong network of architects. This will provide Chuteout with referrals to build up a strong and loyal customer network. Hence, Chuteout implements globally distributed local offices to strengthen these networks.

Key Partners

Maintenance: To ensure that users have no further interaction with their waste after it has been properly disposed of, regular maintenance of the chutes needs to be provided. Chuteout sees maintenance providers as key partners in promoting the successful rollout of the product in new geographic areas. During the initial phase of Chuteout's expansion, local subcontractors will be trained to perform maintenance work at the buildings. Once a certain number of chutes per city have been built during Chuteout's growth phase, the existing local network is leveraged to establish subsidiaries. In this way, Chuteout can benefit from recurring maintenance work.

Local architects: To promote Chuteout, the strategy relies on local and well connected architects who champion the product to housing companies. The standard planning and construction process starts with a client approaching an architect with a plan to construct a new building. The architect is the one responsible for planning and delivering a design proposal. Once this is approved, suppliers are selected either through a tender process or through direct referrals. Most often the latter is done and commissions are awarded directly to known partners. Therefore, close and mutually beneficial relationships with local architects are particularly important to Chuteout's success.

Revenue Streams

Hardware sales for the chute system: At the core of Chuteout's revenue streams are the hardware sales, especially the total contract value of the chute system. The price is calculated based on the size of the building and the requirements of our customers. An offer is created, and the final price is negotiated. This final price already includes the margin on Chuteout's total costs to manufacture a chute system. The chute price will be paid out after successful installation and quality assurance. Most of Chuteout's value proposition is focused on providing premium quality and increasing the willingness to pay of its customers. Sustainability concepts and proper waste management are highly valuable in real estate. In addition to the complete chute system, Chuteout creates revenue with upgrades to existing systems. It provides additional sensors, interfaces, software modules, and analytics. These can be added as independent modules at any time during the lifetime of the chute. As a part of maintenance services, Chuteout also sells spare parts for quick maintenance. It only charges them if the error to be repaired is not caused by its own production process.

Services around the chute system: Besides regular hardware sales, Chuteout collects valuable data about waste origins and composition. This data can be used for the improvement of waste management processes by private or public waste management companies. Potential applications can be the dynamic routing of garbage trucks or the resizing of the truck fleet. By providing an API to Chuteout's database for companies and municipalities for a yearly fee, Chuteout generates an additional income stream.
During the planning and contract phase, maintenance contracts are already closed between the customer and Chuteout. They include maintenance services and materials up to a certain threshold in exchange for a yearly contract fee.

Cost Structure

Variable costs – producing and installing the chutes: As Chuteout is a business with production activities, its cost structure is framed around the process from development to production and installation of the chutes. Chuteout's key competence behind the chute technology will originate from R&D. The modular design of the chute, the simplified integration into the architectural planning process, and the sensors and mechatronics making this system smart are the features that will distinguish the product.
Considering production activities, Chuteout needs the raw material for the steel or plastic channels and electronic components from external suppliers. Processing these materials to the chute requires a factory ground, including machines for milling, welding, cutting, and production staff to operate them. After the production, Chuteout needs to provide logistics and installation teams to set up the chute system at the target building.

Fixed costs – the business behind the chutes: Apart from the chute and production, Chuteout needs to run its business operations to stay sustainable and competitive. Overhead activities like developing networks and partnerships are crucial for its success. This also includes creating awareness in the real estate world that a solution like Chuteout exists and should be implemented. Marketing and a trustworthy sales channel are important communication organs towards Chuteout's potential customers and partners.
As high-quality service and products are expected in real estate, Chuteout offers a five-year warranty for faults arising from manufacturer errors. This service requires additional staff and spare parts. Also, patents are a key resource Chuteout must apply for and regularly refresh to maintain its competitive edge. Chuteout is extending this competitive edge by providing its own in-house software solutions. Also, it provides the chute system and analyzes its own collected data for services, like pay-as-you-throw, or the integration of municipal waste management systems.

Eco-Social Costs

Production and installation: The Chuteout solution needs non-renewable materials, such as plastics and rare earth, to produce some of its essential components. Sourcing these materials emits GHG into the atmosphere and requires intensive physical labor that comes at the cost of the local workforce. Furthermore, local communities involved in mining rare earth often must deal with the immediate environmental and health-related effects of the mining process. As most of Chuteout's potential projects can be found in fast-developing countries outside of Europe, the installation parts must be shipped by freight transport. Additionally, to ensure a successful installation at the construction site, an expert team needs to be flown to the relevant region to oversee and coordinate the process. Both approaches rely on frequent air travel and, therefore, emit a significant number of GHG into the atmosphere. Lastly, working primarily with construction partners in fast-developing countries introduces human rights issues, as their employees often work long hours and receive inadequate payment. This is especially relevant for Chuteout, as implementing its solution relies heavily on the cooperation with local construction companies that often lack transparent business processes.

Operation: Once the Chuteout solution is installed in a building, it uses the energy from the local electricity grid to power its air pumps, sensors, cleaning as well as waste separation mechanisms. Depending on the region of the building, the energy used for these processes might not come from renewable sources and could, therefore, increase the climate-damaging effects arising from the sourcing method. To deal with the smell and minimize the hazardous gases arising from the disposed waste, Chuteout is equipped with a cleaning mechanism. This mechanism employs a variety of chemical cleaning agents to keep the chute system hygienic and guarantee the longevity of the chute's components. However, such cleaning products can cause damage to the environment through air and water pollution.

Eco-Social Benefits

Ecological benefits: Chuteout enables a high pre-sorting quality by using a tri-sorter layout at the end of the chute in the cellar of each building. This design choice raises consumer awareness for the importance of adequate waste sorting and provides a convenient way of disposing waste into the appropriate compartments. As waste can be thrown into the Chuteout solution individually, the need for plastic waste bags and bins in households is reduced drastically. This feature leads not only to less production and use of plastics, but also to less money spent on such items by consumers. The included sensors in the Chuteout solution also benefit the environment as they enable implementing a pay-as-you-throw system. This system has the potential to significantly reduce waste production as users are charged proportionally to the amount of produced waste and, therefore, make more conscious consumption and disposal decisions. Finally, Chuteout provides a more hygienic waste disposal process as the contact to potentially hazardous waste is minimized, and the gathered building waste is disposed of and processed by professionals.

Customer and society benefits: As Chuteout tracks the waste disposal behavior of each household in a building, it offers valuable data that can be used to increase the transparency of the waste production process. This knowledge can be utilized by relevant stakeholders, such as WMS to optimize their waste collection routing. Municipalities and building owners can also profit from this data by better understanding current issues in the waste disposal process of relevant buildings and districts. Lastly, Chuteout also brings along economic benefits by creating additional jobs in the field of chute maintenance. This is especially relevant, as the growth phase of Chuteout envisions the setup of subsidiaries in relevant regions that offer long-term employment potential to the local workforce.

Scenario Fit

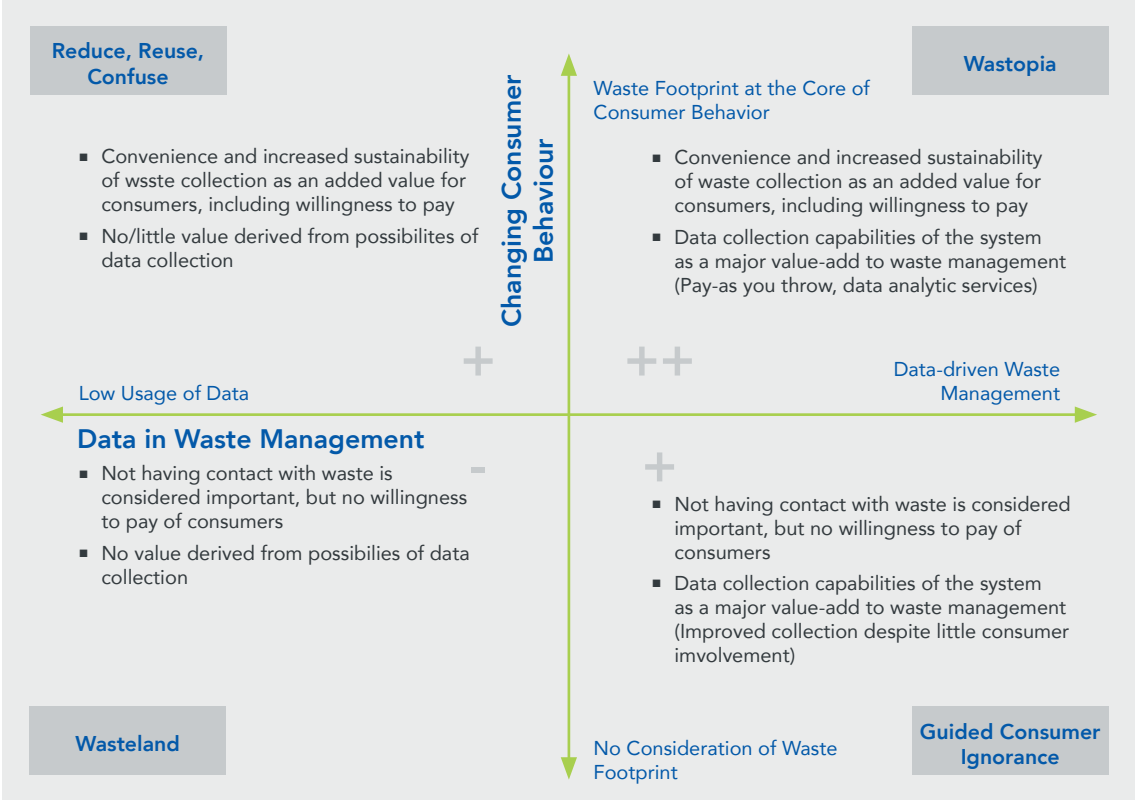
Wastopia: In this scenario, the data availability enables efficient and transparent waste management with Chuteout's product and data service as a key part of the digital waste infrastructure. As the consumers are very conscious about their waste footprint, they derive a high value from the convenience of waste collection enabled by the in-flat chutes, as well as the increased sustainability aspects of producing less waste. This scenario would allow Chuteout to leverage the high awareness about waste to install a connected underground chute system for many houses, providing maximum bundled pre-sorting quality. Next to the consumers, the waste management industry profits from sophisticated technology, which enables the tracking of waste data directly at the source. This allows them to charge tenants by the pay-as-you-throw method.

Chuteout will also be able to sell its data services to the industry, which will support on-demand collection, waste forecasting, and general analytics.

Guided Consumer Ignorance: As consumers do not care about their waste footprint, they only derive value from the convenience of not having to take out their waste, but directly discarding it into the in-flat connection of the waste chute. Their willingness to pay for state-of-the-art technology and high-end design of waste-related products is rather low. This transfers to Chuteout's customers, as housing companies will prioritize other products over a waste chute. Despite little consumer involvement, the solution will be of great value to the waste management industry. The data collection and sorting capabilities of Chuteout will enable an improved waste collection. It will help to reach sustainability targets and tackle the increasing waste production. Waste management companies will have a high willingness to pay for the services, as technology and data will be the two main forces to overcome the need for an efficient waste collection.

Wasteland: In a future where consumers do not care about their waste footprint and there is low data usage in the waste management industry, Chuteout cannot offer a higher value than its competitors. On the one hand, the consumers do not care about waste and have no preference regarding its disposal. This implies that due to human nature, consumers would still value the convenience but would not be willing to pay for Chuteout's special features and high-end technology. Their priorities would transfer to the housing companies, which would make it hard for Chuteout to sell the superior chute systems. On the other hand, Chuteout will not be able to extract value from a non-digitized waste management industry. The waste data would still be collected, but as there would be no counterpart in the collection systems, it would only provide very limited value. Adding to that, they could not leverage pay-as-you-throw and predictive analysis as a selling argument.

Reduce, Reuse, Confuse: When consumers consider their waste footprint, but the waste management industry lacks the data infrastructure to fully leverage this conscious behavior, Chuteout's product and services will not be able to offer their full value potential. Consumers would value having a convenient and luxurious way to dispose of their waste. They would be willing to pay for the high-end technology to increase pre-sorting and therefore recycling quotas, as they care about sustainability. The housing companies will recognize this need and install a high-quality waste chute focusing on hardware. The data would still be collected and offered to landlords, as well as tenants, but Chuteout will not be able to sell it to the waste management industry in this scenario. The data would not provide any direct value to the industry, as there is no counterpart to process and use the information provided through the chute system. This would result in a weaker value proposition to the customers, as well as the overall industry.



Challenges

- **Technology**: Chuteout needs to develop a low-cost prototype to prove the concept of the system. The combination of technologies and its physical size components makes the system highly complex. External investments are likely to be necessary.
- **Scaling**: The number of sales will not be high during the first years of operations, as the projects take time to finish. Even if Chuteout scales fast, it needs to provide qualified installation and maintenance teams in every country it equips with its system.

- **First partner:** Construction and real estate are rather conservative than innovative business areas. Most project partners in construction are acquired via referrals. Convincing an architect and a housing company is difficult without references.
- **Price insecurity:** It is difficult to estimate prices for Chuteout's system and services. Even if Chuteout convinces its first partners, it can be removed from a project if the price increases too much.

Outlook

Acquiring the first architect as a partner and executing the first project will be Chuteout's key milestone for accessing future projects. Chuteout will be one of the leading companies to enable sustainable waste management from single buildings to entire cities. Neighborhoods will be connected by Chuteout's underground disposal system, extending its chutes in buildings, and optimizing waste management on a higher level. Its products and services are based upon consumer convenience. People will demand to be equipped with or connected to Chuteout's waste management system, as it has become the industry standard for constructing new buildings. The system will grow with new technologies, like AI, to process Chuteout's collected data and optimize routing, sorting, and recycling in a circular economy. The data on consumption, waste production, and waste composition will enable new business models to either reuse, reduce or recycle waste or adapt product development and advertisement. Understanding and predicting waste production will be an integral part of nudging consumers towards a more sustainable behavior and analyzing the effect of political measures. Chuteout's core competence will extend into providing a central intelligence for consumption behavior, waste streams, and recycling.

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BATTERX

Automated Battery Detection

Over 12,000 tons of batteries enter the waste circulation each year. Given the increasing use of lithium-ion batteries, the question of a cost-effective and safe separation and sorting process for batteries is becoming increasingly important. Many batteries are not disposed of properly, ending up in household waste instead. 60% of all residual waste bins contain batteries of some kind. When lithium-ion batteries are damaged during the disposal or sorting process, they often begin to burn. Such fire incidents occur almost every week at waste disposal companies in Germany, creating serious problems and financial challenges for operators.

Besides causing high damage to equipment and infrastructure, fires also endanger the health and safety of workers. Given the increasing risk and the magnitude of impact, insurance companies respond by either refusing to insure sorting plants or significantly reducing the coverage of policies while raising premium rates to unaffordable levels. As a result, operators have to shoulder costs incurred not only by equipment repair but also through the loss of revenue during downtime.

Waste disposal companies currently meet this challenge by hand sorting, which is inefficient and expensive. Therefore, a novel and data-driven technology is needed to tackle this challenge. By using deep learning object detection on X-Ray images, BatterX aims to automate battery detection before the waste enters the actual sorting process at the plant.
Reliable pre-sorting of batteries in the waste can significantly reduce the risk of fire, lowering not only the risk of property damage but also costly plant shutdowns. By lowering the risk of fire and making it more calculable for insurers, BatterX also makes insurance possible and more affordable for plants.
Higher automation reduces dependency on hand sorting, thus lowering labor costs and reaching higher accuracy in the screening process. From an environmental perspective, a higher recycling quota for valuable materials is achieved, and the environmental damage is reduced. Finally, a lower risk of fires also results in higher safety for the workers.

Business Model

Key Partners

- Hardware supplier
- Academia
- Insurance companies specialized in waste sorting plants

Key Activities

- Software development
- Supply chain management
- Customer acquisition and maintenance of customer relationships

Key Resources

- Skilled hardware and software developers
- The state-of-the-art battery detection algorithm
- Hardware module including X-Ray detection unit

Value Proposition

Economic Value for Plant Operators

- Lower property damage from fires and fewer operation shutdowns
- Lower insurance premiums
- Reduced labor costs
- Reduced costs from absenteeism due to higher work safety

Technological Value for Plant Operators

- Higher accuracy in the screening process

Environmental Value For Society

- Higher recycling quota for valuable materials

Customer Relationships

- Provide a personalized customer experience
- Provide extensive customer support to strengthen the long-term relationships
- Offer user-intuitive machine operation

Channels

- Trade fairs, professional magazines, and websites
- Associations and conferences
- Cooperation with insurance companies
- Direct sales with equipment manufacturers and plant operators

Customer Segments

Waste Sorting Plant Manufacturing Companies

- Companies that design and manufacture sorting plants and sell them to plant operators enhance their overall system and gain a competitive advantage

Waste Sorting Plant Operating Companies

- Companies that operate existing sorting plants reduce insurance premiums, financial risks of property damage, and loss of revenue

Cost Structure

Fixed Costs

- Hardware production setup together with partners
- Software development costs (training data acquisition, model training)
- Legal approval and certification

Variable Costs

- Module production and cloud based computing
- On-site setup, maintenance, and emergency support
- Software updates
- Customer support and sales

Revenue Streams

One-time Hardware Fee

- Fee for the X-Ray detection unit, customized hardware components, on-site setup, additional machinery integration support

Annual Software Subscription Fee

- Fee for software updates and machine operation training and service

Eco-Social Costs

Social Costs

- Reduced employment opportunities for hand sorters
- Potential exposure of workers to radiation

Ecological Costs

- Carbon impact through energy and material consumption

Eco-Social Benefits

Social Benefits

- Increased number of highly skilled jobs. more varied activities for hand sorters
- Reduced exposure to potentially hazardous waste

Ecological Benefits

- Increased sustainability and energy balance of batteries and recovery of scarce resources

Value Proposition

When undetected batteries reach the shredding process, they will likely catch on fire, creating substantial financial challenges for sorting plant operators. By reducing risk, BatterX's main value proposition to customers lies in the amount of the savings it secures, namely reduction in repair and operating costs, loss of revenue as well as in insurance premiums.

Repair costs and revenue loss: Undetected batteries within the waste stream pose a variety of potential financial losses for plant operators. The solution of BatterX detects batteries entering the sorting facility with high accuracy, thus greatly reducing the probability of battery fires. This, in turn, lowers the potential amount of property damage, therefore saving the costs of repairing infrastructure and equipment. Less operational shutdowns mean less revenue losses and fewer non-fulfillment costs incurred during downtime.

Insurance premiums: Previously, insurance companies either refused to insure sorting plants due to the lack of data combined with the high impact of incidents or charged a premium that most operators find unaffordable. With the installation of BatterX, data becomes available and transparent. As the risk and impact of these events become more finite and calculable, insurance companies can start to offer policies at a more affordable rate.

Operation costs: Labor costs associated with battery detection as well as absenteeism shrinks, since employees' work is now reduced to removing batteries detected by the AI algorithm. This is a much safer and more efficient process compared to the previous method of hand-sorting all waste in search of batteries. As detection by hand-sorting is labor-intensive, the adoption of BatterX allows for a reduction in the number of employees dedicated to this process. The combination of increased work safety and the reduction in monotony raises employee morale, further contributing to efficiency and thus lowering operation costs.

Customer Segments

By providing a solution that can be integrated into existing plants and developing plants, BatterX targets two customer segments: sorting plant operators and sorting plant manufacturers. Specifically, BatterX is relevant for sorting plants that process residual household waste, lightweight packaging waste, and metal packaging waste, being the waste types with a significant battery contamination quota. Both customer segments require differentiated sales approaches and a different scope of support for purchasing and installing the BatterX module.

Waste sorting plant manufacturing companies: Such companies design and manufacture sorting plants and sell them to the end customers, which operate the plants. Since fires caused by batteries are a huge risk for plant operators, these companies buy BatterX modules to integrate battery detection units in their sorting plants and thereby enhance their overall system with the latest technology. In this way, sorting plant manufacturing companies become more attractive to their customers. Because they offer a system solution that detects batteries right as they enter the sorting plants, they gain a significant competitive advantage over their competitors. They can increase their prices and customer base simultaneously.

Waste sorting plant operating companies: These are companies that are operating existing sorting plants. They purchase BatterX modules to reduce the risk of fire and consequential financial risks of property damage and loss of revenue. Furthermore, they benefit from lower operational costs due to automating the battery screening process. Another main benefit for plant operators is the reduction of insurance premiums through the adoption of BatterX. All in all, BatterX represents a valuable and cost-reducing solution for plant operators. Installing the BatterX module on already existing plants requires additional support and raises the installation costs.

Customer Relationships

BatterX aims to establish long-term relationships with all customer types through various means. As BatterX's software and hardware are highly customized for each plant and are under constant development, a personalized customer expe-

rience, as well as extensive customer support, are essential for BatterX to establish close customer relationships. Close and trusting relationships with its customers are a high priority for BatterX as it relies on a continuous stream of data from its customers to keep the detection software up-to-date.

Provide a personalized customer experience: From sales through installation to updates, BatterX maintains close relations with its customers. On-site operative training is provided during and after the installation to train the sorting plant employees for operating the module and continuous troubleshooting. By providing hardware maintenance as well as emergency support, ongoing customer care is assured.

Provide extensive customer support: By providing transparency and long-term servicing of both hardware and software, BatterX establishes customer trust in its technology, product, and services. This trust is what facilitates the sharing of data from customers to BatterX, essential for keeping the detection algorithm up-to-date. The plant operators have a possibility to integrate a feedback loop, sharing with BatterX relevant data on the waste composition, for example, occurring anomalies in the data. BatterX uses the data to constantly improve the detection quality. This feedback loop ensures that, in the long run, all sorting plants enjoy the benefits of up-to-date battery detection software.

Optimize for users: For the BatterX solution to work efficiently, the interaction of plant sorting employees with the detection dashboard must be an intuitive and frictionless experience. In order to achieve this goal, BatterX prioritizes feedback and requests regarding the usability of its interface.

Channels

BatterX uses a number of different channels in order to sell its products. Individual channels support different parts of the sales cycle. Some channels are used for creating brand awareness within the waste sorting industry, whereas others are used for lead generation and strategic partnerships.

Trade fairs, professional magazines, and websites: These channels help BatterX's marketing efforts to educate the market about the problem of fires caused by batteries and how the BatterX battery detection unit solves this problem. In addition, these channels also aid in increasing the brand awareness of BatterX as the state-of-the-art AI based battery detection unit within the sorting industry.

Associations and conferences: Associations and conferences serve as touchpoints with representatives of sorting companies. Sorting company executives have the opportunity to discuss their specific concerns with BatterX representatives ranging from discussing the economic feasibility of BatterX to the integration of BatterX within their existing sorting plants. This discussion helps to increase the openness of waste sorting plant managers to BatterX while also generating important leads to pursue sales purposes.

Cooperation with insurance companies: BatterX decreases the risk of fires in sorting plants, thus directly reducing the financial costs incurred by insurance companies. It is then in the interest of insurance companies to recommend that waste sorting plants integrate BatterX in their plants to reduce the risk of fire. Insurers could offer a significant reduction in the insurance premium to waste sorting companies using the BatterX module. Therefore, BatterX maintains a close relationship with insurance companies and proves to them that BatterX reduces the specific fire risk.

Direct sales with equipment manufacturers and plant operators: The target segments - equipment manufacturers and plant operators - will be directly approached by our sales representatives.

Key Activities

BatterX engages in a multitude of activities to deliver its value proposition, including software development, supply chain management, and customer support.

Software Development: BatterX develops a module consisting of hardware and software components to detect the presence of batteries in waste. Previously, detection based on standard image recognition alone yielded poor results as batteries contaminated with waste lose their visual distinction. One of the key activities of BatterX is to train its deep learning algorithm on the X-Ray transmission imaging of the waste so that it efficiently detects batteries that are built-in within electronic products or obscured by waste. The integrated sensors provide the images, which the AI searches for shapes associated with batteries. As the composition of waste changes, so does the shape of batteries within the images. Therefore, another crucial activity is to continuously update the algorithm.

Supply chain management: As BatterX outsources the production of hardware module components to an external manufacturer, managing this partnership is a crucial key activity.

BatterX closely collaborates with suppliers to ensure that the production follows the custom blueprint and quality standard set by BatterX. This is especially important as the production is not standardized, and the module is partially customized for each order to be seamlessly integrated into the different sorting facilities.

Customer acquisition and maintenance of customer relationships: Another critical activity is acquiring customers since sorting facilities are large establishments that are few in number and geographically distributed. This, along with the nature of the customers' operating model, leaves few channels for contact. Besides approaching associations, direct sales also play an essential role in generating leads for BatterX. With new customers comes the activity of identifying and evaluating their hardware customization needs, while existing customers have evolving detection needs that require software updates.

Key Resources

There are three central resources for BatterX. Hardware and software represent one key resource each, as both are included in the product offered to customers. Additionally, human resources are needed to develop hardware and software.

Physical resources: The central part of the BatterX module is the scanning equipment that supplies X-Ray imagery of waste to the AI algorithm. This includes an operating console, a high-frequency X-Ray generator, a detector, and metal shielding to protect the external environment from any radiation. As the setup of the facilities differs across customers, the dimension of the module has to be adjusted for each order.

Intellectual resources: The core added value for customers is delivered by the algorithm that detects batteries within other waste streams in real-time. Since the composition of waste is constantly evolving, continuously collecting data and improving the deep learning algorithm is essential to maintain the value proposition of BatterX. To protect its intellectual property, BatterX continuously files patents for its software and hardware inventions. Patents represent a key resource for BatterX, setting it apart from its competitors.

Skilled hardware and software developers: As the module of BatterX comprises both hardware and software components, a skilled workforce is crucial to the successful production and deployment of the product. As a high degree of customization is needed to meet the differing facility requirements of customers, the knowledge and expertise of employees represent some of the major resources within BatterX. Hardware developers design the physical X-Ray module while carefully balancing customers' needs with manufacturers' capabilities and closely collaborating with suppliers to ensure the outsourced production matches the intended requirements. Software engineers focus on developing the state-of-the-art AI algorithm that uses collected data to detect batteries hidden among different types of waste.

Key Partners

Among the key partners of BatterX, there are three main categories. First, hardware manufacturers are necessary to build the scanning equipment. Second, BatterX closely collaborates with researchers to develop state-of-the-art detection algorithms. Lastly, insurance companies evaluate the amount of risk reduced by installing the BatterX module in order to offer sorting plant operators lower insurance premiums.

Hardware supplier: BatterX partners with an external manufacturer who produces the custom design module components according to BatterX's specifications. Thereby, it forgoes in-house manufacturing in favor of outsourcing to access specialized expertise without needing to tie down significant capital for infrastructure and equipment. In addition, BatterX benefits from the lower production costs achieved by external manufacturers who can fully utilize their facilities to reach economies of scale. BatterX maintains a strong partnership and open communication to ensure the quality of the work and assembles the delivered components itself at the company's premises.

Academia: To develop the battery detection algorithm, BatterX partners with academic researchers from the fields of waste management and AI. The waste management researchers provide information on the emerging trends in waste compositions and share the training data collected through sampling experiments. On the other hand, researchers in AI provide valuable insights based on the latest machine learning research to optimize the BatterX battery detection algorithm.

Insurance companies: The module of BatterX bridges the gap of trust and information between insurance companies and sorting plants. So far, insuring sorting plants against

burning down from battery fire was either unavailable or unaffordable. BatterX aims to change that by partnering with insurance companies to promote the installation of the BatterX solution among sorting plants, making the risks more calculable. This, in turn, makes insurance possible and more affordable for plants. BatterX actively approaches insurance companies who are specialized in sorting plants to promote the recognition of its module.

Revenue Streams

One-time Hardware Fee: Upon purchase of a BatterX hardware module, a one-time fee is charged. In addition to the X-Ray detection unit, this fee comprises further customized hardware components as well as the on-site setup and training of workers. For customers who integrate the BatterX module in their existing sorting plant, an additional machinery integration support is offered. This support ranges from engineering consultancy services to hands-on machinery installation services. Such a service is especially relevant for sorting plant operators who do not have the in-house competence to integrate BatterX into their existing plants.

Annual Software Subscription Fee: The yearly fee comprises two software-related services: software updates as well as machine operation training and service. Different companies that process different types and quantities of waste require different levels of support services. For instance, a waste sorting plant that processes a larger quantity of waste most likely requires more employees to be trained as well as more troubleshooting support for its plants. Thus, the pricing for the yearly software subscription fee is based on the size of the sorting plant.

Software update fee: Over time, the waste composition changes. Due to this fact, the battery detection algorithm continuously needs to be adapted to these changes in order to maintain a high detection accuracy. Therefore, BatterX updates its software with enhanced detection algorithms using waste composition data collected from operative BatterX modules.

Machine operation training and service: BatterX conducts training for machine operators on how to use the BatterX battery detection unit. The training takes place multiple times a year. It consists of training for new employees and existing employees who need refresher courses (e.g., regarding machine safety and radiation security). New functionalities of the BatterX software are introduced in these training sessions as well. Furthermore, a service in the form of troubleshooting support is offered in case a problem cannot be solved by the operators' employees.

Cost Structure

Fixed Costs:
Development of the BatterX module: Before generating revenue by selling BatterX units, BatterX invests in developing its technology first. Machine and software development costs account for large parts of BatterX's total expenses, especially in the first years of its installation. Machine development costs include setting up an X-Ray detection module production together with Batterx's manufacturing partners. The training data collection for the BatterX AI based algorithm, the algorithm's training, and on-site validation constitute a significant share of the software development costs.
Legal approval and certification: Exposure to X-Ray radiation is harmful to human health. Therefore, BatterX needs to go through an extensive legal approval and certification process for its X-Ray detection modules. Besides certification costs, BatterX needs to improve the design of its modules to meet the legal regulations, requiring additional costs.

Variable Costs:
Variable costs include production costs for BatterX modules as they increase with each machine sold. Since BatterX plans to outsource its production to a manufacturing partner, BatterX needs to use its negotiation power in order to keep the production costs low. As BatterX provides customized solutions for the sorting facilities, module production costs also vary for different modifications of the BatterX module. The demand for cloud based computation resources also increases with the growing customer base, resulting in additional costs.
On-site setup, maintenance, and emergency support: After a BatterX module is sold, this module is customized and integrated into the customer's plant. Following the on-site setup, this module is maintained and supported in case of an emergency, which leads to additional variable costs.
Software maintenance: An increasing amount of training data and further detection algorithm development also boost the software complexity, which requires additional development and maintenance costs.
Customer support and sales: To keep a good quality of customer support with an increasing customer base, BatterX needs to employ more technical support engineers and an enlarged sales team.

Eco-Social Costs

Social costs: BatterX automates the battery detection task. Therefore, with BatterX, workers do not have to screen through the entire waste but just sort the batteries in specific areas of the waste. This significantly reduces the number of workers needed for sorting the waste. As handsorting is low-paid manual work that does not require specific education, removing this job opportunity hurts some of the most vulnerable employees and job seekers that have few other options to consider. Workers who were previously employed as hand sorters in waste sorting facilities may have difficulties in finding a new position as waste sorting plants are spread out regionally. Furthermore, X-Ray technology may impose additional risks of workers' exposure to radiation, which could lead to severe health issues. These aspects must be considered during the development of the BatterX module and monitored by an extensive approval and certification process.

Ecological costs: The production and operation of BatterX requires energy. The production of the module also requires a considerable amount of metals and other resources. The electricity required for the manufacturing and operations of the BatterX detection machine and supporting cloud based computation services comes from the grid, which currently provides electricity from a mix of renewable and non-renewable sources. In addition, different parts of our machine are sourced through complex supply chains. Since customers are geographically distributed, the delivery of heavy machinery must take place over long distances as well. This also adds to the carbon impact, considering that most transportation consumes non-renewable carbon based energy sources. To reduce its environmental footprint, BatterX considers offsetting its carbon emissions.

Eco-Social Benefits

Social benefits: BatterX increases the number of batteries that are recycled from waste. To recycle this increased amount of batteries, the battery recycling industry has to increase its plant capacities, which increases the number of higher skilled jobs. Moreover, through automating the de-

tection of batteries using X-Rays instead of hand sorting, BatterX significantly reduces the exposure of hand sorters to potentially hazardous waste. In the long-term, this reduces sick leave among workers and improves their health. By automating the battery detection part, the monotonous job of battery hand sorting is upgraded with more varied activities, such as maintaining the BatterX module. For hand sorters, this leads to improved pay and positioning in the labor market. As a newly established company, BatterX itself also creates a range of highly skilled jobs in software development, manufacturing, technical support, and sales.

Ecological benefits: By detecting batteries in the waste so that they are eventually removed and recycled, BatterX increases the number of recycled batteries. This helps increase the sustainability and energy balance of, particularly inferior batteries. Detecting batteries in waste also helps recover scarce resources such as zinc, iron, aluminum, lithium, and silver. Batteries also contain hazardous substances to health and the environment, such as mercury, cadmium, and lead. Sorting out these batteries prevents these materials from entering the environment. BatterX also reduces fires caused by batteries in sorting plants, thereby reducing the CO2 and hazardous gasses released into the atmosphere when waste gets burnt.

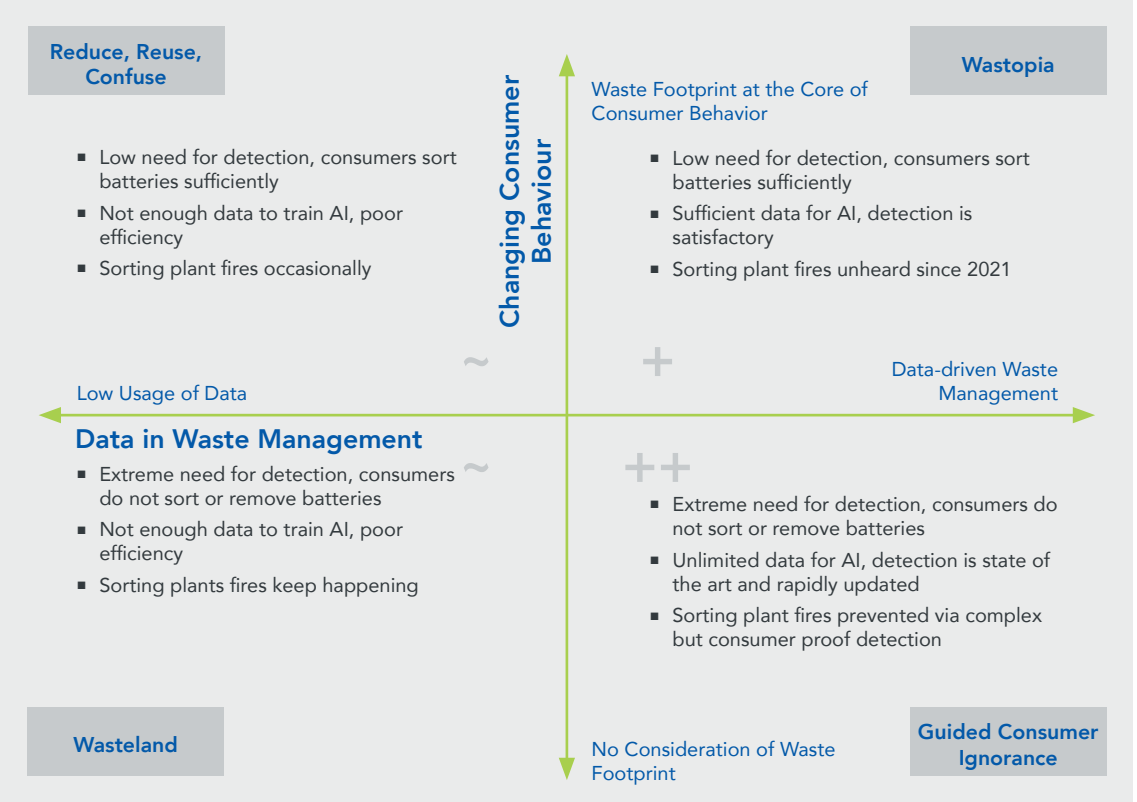
Scenario Fit

Wastopia: Given the growing information and awareness around waste footprint, consumers meticulously remove batteries from discarded electronics and sort their waste in a near-perfect manner. As a result, the need for detecting batteries is significantly decreased. While on occasion, there are still some unintended batteries that enter sorting facilities, these are easily detected and removed. As these incidents are very rare, previously collected image data becomes nearly obsolete, thus limiting the potential of AI. However, BatterX's detection algorithm is supported by IoT data available from all other areas and processes of waste management, yielding a detection performance that is still above average. BatterX can expect stable but mediocre market returns, driven by the need to replace hand sorters.

Reduce, Reuse, Confuse: In this world, consumers do their best to remove and sort batteries. However, insufficient information on casings of electronic products misguides them, which sometimes leads to incorrectly disposed batteries. The lack of data in waste management makes it difficult also for sorting plants to leverage advanced technologies. Incidents are not frequent enough to collect sufficient amounts of training data for deploying AI. Reasoning that the rare occurrence is not worth the cost of human labor, companies also cut back on the old method of hand-sorting all incoming waste to detect batteries. Similarly, companies are also reluctant to invest in detection modules, so the solution of BatterX may suffer difficulties entering the market.

Wasteland: Regardless of their willingness, consumers are seduced to care less about their waste disposal behavior due to missing guidelines that would require adequate data. Not receiving any data from other stakeholders, sorting plant facilities are ill-equipped to deal with the resulting chaos. Without advanced technologies to mitigate them, sorting plant fires become commonplace. Sustainability and waste-related jobs are already considered less prestigious despite their high demand. Still, handsorting turns into one of the most unattractive jobs. Although there is an initial high interest and demand for the solutions of BatterX, it fails to realize its potential due to little data.

Guided Consumer Ignorance: While consumers care little for their waste footprint, their digital footprint makes them predictable enough for waste management companies. From grocery shopping bills to e-commerce orders, disposal be-



havior is forecasted and forwarded as potential input for sorting facilities. These are then matched with data transmitted along the entire waste chain from sources such as garbage trucks and smart bins. The sorting plants are used to see complex, unsorted waste mixed with electronics. It leverages cutting-edge technology to prevent batteries from entering the sorting process. This also includes the modules of BatterX, which are extremely high in demand. Customers are highly willing to share data to improve detection accuracy in return for discounted fees. BatterX has the potential to become a market leader with its state-of-the-art algorithm. scenario.

Challenges

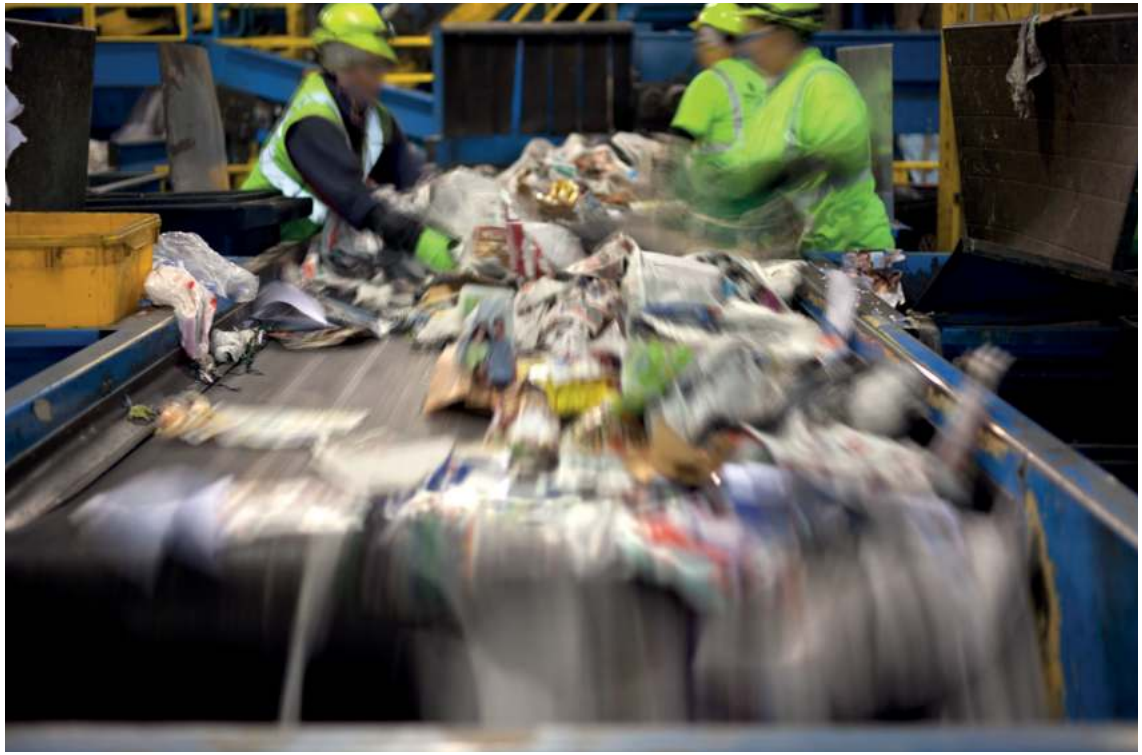
- Development of the AI based battery detection software with a high accuracy
- Acquisition of customers who are skeptical about the use of AI
- Integration of hardware components into one seamlessly functioning system within sorting facilities
- Finding a partner company for manufacturing the X-Ray scanner
- Providing customer support for hardware as sorting plant facilities are geographically distributed
- Ensuring the growth of BatterX through effective sales strategies
- Continuous research is necessary to keep up with the ever-changing composition of waste

Outlook

The future of BatterX is projected into three phases: Pilot, transition, and expansion.

The pilot phase of BatterX will start with BatterX and its academic partners collaborating to develop the battery detection algorithm. Research involves cataloging and labeling a large amount of waste X-Ray Transmission imagery, which is then used to train the deep learning algorithm to recognize shapes of batteries. Soon after, different software module versions are built to test different setups and scenarios that resemble real-life facility environments.

After the first working integration of the detection algorithm and module, BatterX proceeds to work together with hardware suppliers to deliver the module to the first customers. Once the prototype passes the live testing environment,



BatterX begins full-scale production and sales. BatterX expects some of the customers to opt for the discounted pricing model where BatterX receives their operational data in return.

The vast amount of data gathered through customers will be used to advance the BatterX detection algorithm. The peak detection performance would allow BatterX to differentiate itself significantly from competitors. Given the high detection rates, it can be expected that the insurance companies may oblige plant operators to install battery detection modules.

Sebastian Serna, Iuliia Lomakina, Claudius Seitz, Emanuel Gerber, Florian Kristof

SORVIS.IO

Moving Sorting Plants Forward

sorvis.io

Waste sorting plants are designed for a specific waste quantity and composition with the goal to optimize mass throughput. In practice, however, the composition and quantity of waste fluctuates over time. Thus, plant operators struggle to maintain an optimal utilization rate of their plants while also guaranteeing high sorting quality. Complex and intransparent waste flows make it especially difficult to get insights into the utilization of the plants. With no sensor information along the process line, plant operators have difficulties understanding bottlenecks or idle times that occur at different stages along the sorting process, therefore inefficiently allocating plant resources.

To increase the efficiency of the sorting plant, Sorvis offers a fully integrated, customized plant suite for continuous waste flow monitoring and control. On the software side, Sorvis uses process mining to detect and report inefficiencies such as bottlenecks or idle times. The hardware component consists of various sensors installed at critical points along the process. By using sensor data from the plant in combination with the process mining algorithm and trained AI model, Sorvis can apply predictive flow control and adjust plant parameters to optimize plant throughput. Adjusted parameters are, for example, conveyor belt speeds that are individual to each machine. In addition, Sorvis connects to the Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM) systems integrating all available business information of the sorting plants. Thus, plant operators can monitor and optimize every process stage from waste delivery to order fulfillment.

Sorvis mainly targets new sorting plants, closely working with its key partner, plant builders, to integrate the suit in the original plant layout. Revenues are generated from three key streams: one-time installation payment, tiered subscription model, and customer support fees. Sorvis places high emphasis on solution customization and outstanding customer support. It aims to establish long-term, trustworthy relationships with the plant owners that enable future upselling opportunities of new product features, such as plant layout simulations and predictive maintenance for the machinery.

Business Model

Key Partners

- Sorting plant builders to integrate Sorvis in new plants
- Sorting machine and sensor manufacturers to provide access to their interfaces
- Contractor companies to install and set up sensors and getaway devices

Key Activities

- Developing software
- Subcontracting companies to install sensors
- Customizing offerings for plant owners
- Providing customer support and software maintenance

Key Resources

- Expert network in the sorting business
- Skilled sales professionals, project managers, and software developers
- Data from machinery, ERP, and CRM systems

Value Proposition

- Improved efficiency and utilization of the sorting plant
- Complete visibility over sorting processes
- Customization of the solution to the specific plant's needs
- Optimization of logistics and order fulfillment
- Increased communication transparency with other value chain players

Customer Relationships

- Tailoring Sorvis to the specific configuration of plant's sorting machines and business needs
- Training customers on the effective software usage
- Offering continuous customer support

Channels

- Partnering up with plant builders, so they recommend the implementation of Sorvis in new plants
- Online and telephonic sales task force for acquiring and guiding new customers

Customer Segments

- Existing sorting plants that want to have better visibility of their ongoing processes
- New sorting plants that want to invest extra capital for efficient processes

Cost Structure

Initial Investment

- Software development and IT Infrastructure
- Waste sorting expert engagement
- Company legal setup and solution patent costs

Fixed Costs

- Personnel costs
- IT Infrastructure and cloud computing costs
- Office rent
- R&D of new features

Variable Costs

- Marketing & sales
- Customer support center
- Equipment installation contractor fees
- Sensor purchasing

Revenue Streams

Immediate Revenues

- Recurring revenues through tiered pricing subscription
- Variable revenues from customer support fees
- One-time payment for sensors and installation by end users

Possible Future Revenues

- Optimal configuration models for new plants

Eco-Social Costs

- Sensors and wiring are non-renewable
- Data analysis process is energy intensive which creates emissions
- Process optimization and automation could lead to job eliminations on all employee levels

Eco-Social Benefits

- Less power consumption due to more efficient plant resource utilization
- Fewer workplace injuries due to a decrease in manual repair and maintenance
- Higher waste processing rates in the entire industry due to better stakeholder communication

Value Proposition

Plant efficiency optimization: Sorvis collects all the available data from sensors from the waste sorting process. This data stream is fed to an AI model that learns to predict the waste flow through the plant. Sorvis then uses process mining to suggest adjusting plant parameters such as conveyor belt speeds or machine settings. Using these adjustments, the sorting plant produces maximum waste throughput while preventing bottlenecks and overhead production. In addition, Sorvis' integrated ERP and CRM systems enable an analysis of all the available business information of the sorting plants, optimizing every process stage in the plant from waste delivery to order fulfillment.
Complete process visibility: Sorvis collects, analyzes, and presents the data from the machines in the sorting process. This gives the plant operators a complete overview of the processes inside the plants so they can supervise the waste flow through the Sorvis' interface. If there is any problem occurring, such as a bottleneck, Sorvis sends a warning so that the operator can react immediately to fix it.
Solution customization: The sorting process is highly variable as plants differ in facility sizes, installed machinery, and types of the handled waste. Thus, Sorvis needs to customize the solution for each plant to achieve maximum efficiency improvement. Customization happens both for hardware and software components. On the hardware side - plants can choose between different sensor types across the process line. Regarding the software, plants can select what type of machinery and business systems are integrated into the plant control suite.
Stakeholder communication transparency: Sorvis gives the sorting plant information about their waste flow, particularly the maximum waste inflow they can accept and the maximum number of orders they can fulfill without compromising the quality of the output. This enables better communication among the value chain players, which results in more effective collaboration and new opportunities for the full automation of the logistics system.

Customer Segments

Sorvis' customers can be grouped depending on whether the plant is already running or is going to be built.

Existing sorting plants: As these customers already have an established sorting process, Sorvis' co-creation process requires a detailed understanding of the current plant operations. Thus, a project manager is assigned to each sorting plant to evaluate the existing machines and discover which data is already available for integration and which data needs to be collected through the hardware installed by Sorvis. However, for this customer segment, co-creation faces two significant challenges. First, Sorvis might struggle with consolidating the data, if existent, from the different systems of the plant. Second, the sorting plant might have limited space for new hardware installation necessary for the control suite, so Sorvis might need to adapt to the existing space constraints.

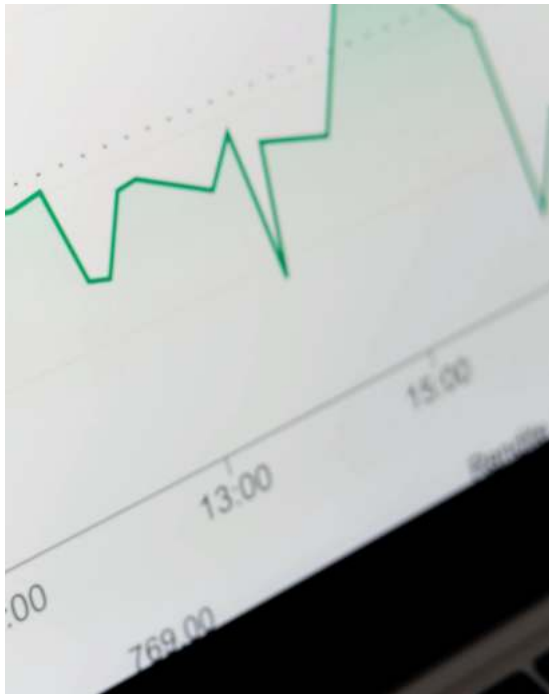
New sorting plants: For these customers, Sorvis also deploys project managers who actively participate in the initial design of the sorting plant that is optimal for Sorvis' integration. In collaboration with new plant builders, these managers guide the customers through the entire purchasing process, suggesting which machines should be bought, which sensors are needed to extract the data from the sorting process to feed the algorithm, and how the sorting plant should position and connect all the machinery. The goal of the project managers is to show how the proposed structure of the plant maximizes the efficiency of the sorting process.

These new plants are our primary target. As they are not constructed yet, there is more flexibility to choose the machinery that works perfectly with the plant control suite and there are no space limitations inside the sorting plant for the required sensors. Moreover, there is less overhead work since no consolidation of the existing data is needed. These advantages remove most of the entry barriers for Sorvis and enable the company to provide the service to the majority of new plants.

Customer Relationships

Co-creation and tailoring: Sorvis aims to build trustworthy, long-term relationships with the sorting plant managers, who are essential for software adoption in the plant. For each plant, Sorvis assigns a project manager. This manager is responsible for closely connecting to the sorting plant owner and understanding the specific plant's needs. The goal of the project manager is to find out which types of machines and sensors are already available in the sorting plant, and which kind of data is currently missing. By doing this, Sorvis can create a layout for the hardware components and customize software modules to optimize the plant performance. In addition, the dedicated project manager reconnects with the previous customers annually to upsell the new features.

Customer support and training: As Sorvis highly values its customers and aims to establish long-term collaboration, it invests heavily in high-quality customer support to help the sorting plant owners with technical difficulties. To ensure efficient and timely support for each sorting plant, Sorvis has a highly skilled team of engineers and software professionals responsible for solving software problems and troubleshooting if any sensor or technical equipment gets damaged. In addition, Sorvis emphasizes customer training. After the software deployment, the dedicated training team would provide extensive training on all the software features to ensure all users have an in-depth understanding of the suite. Moreover, each time the customer purchases a subscription upgrade or a new feature is added to the current subscription, Sorvis would provide a series of workshops and on-site



training to help employees adjust to the new developments.

Channels

Partnerships with plant builders: Plant builders have valuable relationships with plant owners who plan to construct a new plant or run an existing one. Therefore, plant builders are a strategic channel to get new customers. There are two reasons why the plant builders should be interested to cooperate with Sorvis. First, they can increase customer satisfaction by optimizing the sorting processes in the new plants with an advanced plant control suite. Second, referrals are profitable for the plant builders as they share with Sorvis the installation fee for the sensor and IT hardware needed for the process optimization.

Online and telephonic sales: Sorvis employs sales personnel that reach out to customers with cold calls and emails to make the first contact and increase the company's recognition. If the plant is interested in Sorvis, these employees assign a project manager to each potential customer, who guides them through the purchasing process and demonstrates how Sorvis can improve efficiency and machine utilization in the sorting plant.

Support and training center: This channel is important for customers with any technical difficulties like sensors failing or software encountering errors, or for those who would like to receive additional training. To help those customers, Sorvis runs a customer support center for each geographic region that can be reached via mail or phone.

Website with information about Sorvis: This website gives transparency to all the key competencies of Sorvis. Plants interested in Sorvis can use the website to get information about different pricing, explore the product demo, and read reviews of the existing customers. Further information for sales and support is also displayed on the website.

Key Activities

Sorvis aims to improve the efficiency and utilization of sorting plants to help them find the perfect balance between quality and mass throughput. To reach this goal, Sorvis focuses on four key activities.

Developing software: The three main software features of Sorvis are collection, analysis, and visualization of the data. For the collection of data, Sorvis programs and integrates all the PLC system interfaces. For the data analysis, Sorvis has to develop, train and test an AI Model that works with a process mining algorithm to identify bottlenecks and suggest improvements in the sorting process. Finally, data visualization requires a client that can be installed on the most common operating systems or can be available on the web.

Subcontracting companies to install sensors: In the initial stage, supplying and installing sensors are not part of Sorvis core competencies. Therefore, Sorvis utilizes subcontractors for those tasks. By doing so, Sorvis can keep costs low as fewer workers are on a payroll. Additionally, a network of competent subcontractors across Europe allows for fast engagement of workers if a technical problem with the sensors arises.

Customizing offerings for plant owners: Sorvis is customized depending on the plant size, waste type, and sorting operations. A Sorvis employee maps out the sensors that the plant may already have and determines which sensors need to be bought and where they should be installed. Also, depending on the information needed by the plant manager, the software platform visualization is adapted. While the customization increases the complexity of the software, it allows Sorvis to be implemented in every sorting plant.

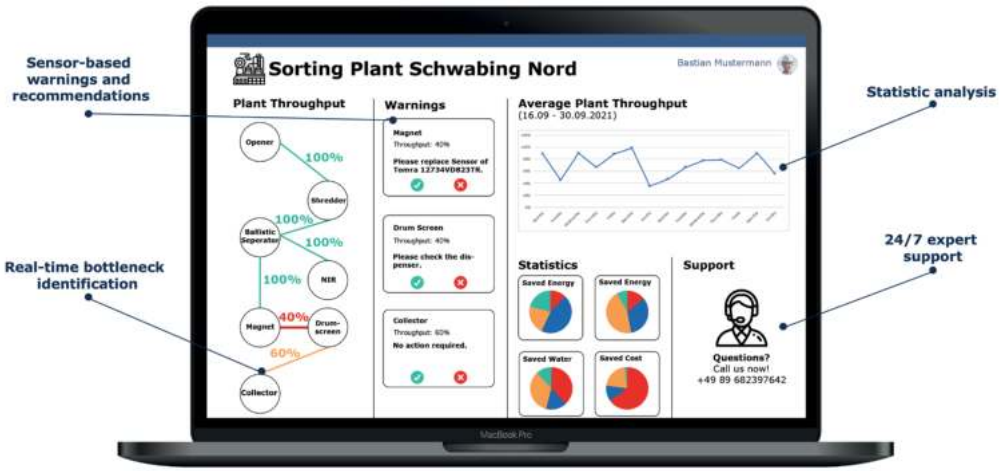
Providing customer support and maintenance of software: As Sorvis values long-term relationships with its customers, it considers customer support to be one of the key activities. Sorvis assists customers when technical problems arise, offers training on the new and existing features, and provides ongoing maintenance of the software to account for operating system updates and other changes in the software environment.

Key Resources

For the successful development of Sorvis' solution, an expert network with knowledge about the sorting sector is essential. Since sorting plants currently work without sharing data or expertise, it is necessary to gain insights from experts about the current processes and the best ways to optimize them. Having relationships with the waste sorting experts significantly mitigates the risk of developing a product with low usability.
Although external experts are important, Sorvis also aims to establish an internal team with various areas of expertise, such as software development, project management, and sales. Software developers create the core product, and it is necessary to hire talent from process mining and AI modeling fields. A proficient sales task force makes it possible to strengthen Sorvis brand name across Europe and to gain a large customer base, while project managers establish close connections with the sorting plant owners to guide them through software integration and future upgrades.
Another critical resource for Sorvis is data from machinery, ERP, and CRM systems. Intending to increase the plant's efficiency, the combination of this data, fed to the process mining algorithm results in the best possible optimization solution. In turn, this process mining algorithm provides powerful insights into processes and their bottlenecks. These insights can then be made accessible via visualization of the underlying sequence of steps.
Building upon the insights from the different data sources, the process optimization AI model helps the plants improve their productivity. Starting with recommendations to the operator, the model further learns how changes impact the overall system. This enables the AI model to directly adapt the parameters of the plant to improve efficiency.

Key Partners

For Sorvis, the most important partners are companies that build new sorting plants or equip existing plants with new machinery. Collaboration with them allows Sorvis to integrate necessary hardware and software components into plants while they are being built or when additional machinery is added. Simultaneously, these companies are significant sales channels.
Further key partners are sorting machine manufacturers. Implementing interfaces for data collection into their machines' designs allows Sorvis to easily integrate all the plant equipment into one system. In addition, since many of these manufacturers currently only provide limited access to their systems, a close partnership is helpful to gather large amounts of raw data for the solution development.
Similarly, sensor manufacturers are essential for supplying sensors for data collection currently missing in sorting plants. This partnership also enables Sorvis to gain deeper insights into the behavior of the sensors to improve the accuracy of the waste flow predictions. Furthermore, a connection to those manufacturers allows for easier configuration of the sensor data into the Sorvis' software.
Other key partners are companies contracted to install sensors and gateway devices into sorting plants. As Sorvis is mostly concerned with data analysis and subsequent adaptation of the processes these contractors ensure that additional sensors or gateway devices are installed and set up. In close cooperation with them, Sorvis creates an optimal layout for all the hardware components in the plant, lowering costs for Sorvis' deployment.
Finally, ERP and CRM software providers are important key partners as well. Accessing their data by creating an interface to their software is essential for the process planning suite that combines both business and machinery data, optimizing plant operations at every stage.



Revenue Streams

Sorvis can generate revenues from three different sources in the short term. In the long run, two other revenue streams may emerge as Sorvis analyzes aggregate data from all customers and establishes partnerships with the government.
One-time installation and setup payment: Sorvis charges sorting plant owners a fixed fee that would include sensor provision, installation, and system set up. From existing plants, Sorvis receives this fee in full. In contrast, the fee received from new plants is equally split between Sorvis and plant builders, including process mining software as part of its original package for plant construction and set up.
Tiered subscription model: As Sorvis plans to customize solutions for the specific needs of each sorting plant, it utilizes a tiered pricing subscription. This pricing model allows Sorvis to offer multiple packages with different features and prod-

uct combinations available at different price points. Customers receive detailed guidance on which feature combination to choose that would fit their budget and goals. In addition, this type of pricing allows Sorvis to maximize revenue extracted from each customer, while also providing an easy upsell opportunity as plants outgrow each tier.
Customer support fees: Companies pay Sorvis for utilizing the customer support center. The fee is calculated based on the pay-per-use model where the user has to purchase a token before being able to open a support ticket.
Future revenue streams: As Sorvis collects more anonymized aggregate data from its customer base, it can apply machine learning algorithms to identify the ideal plant configuration that maximizes waste flow efficiency. Thus, Sorvis would be able to sell the derived insights to new plant builders. In addition, Sorvis would be able to deeply understand the energy efficiency of the plant operations. Thus, it could receive permission from the government to sell energy efficiency certificates to plants that qualify them for governmental subsidies or other benefits.

Cost Structure

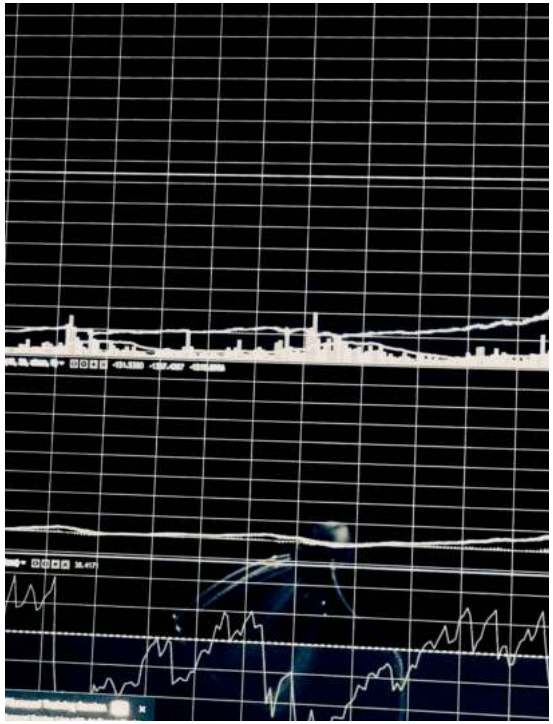
As Sorvis progresses to become the leading provider of sorting plant control systems in Europe, it encounters three major cost categories. These consist of initial investment costs and remaining daily operational costs that can be split into fixed and variable costs.
Initial Investment: In the first step of its journey, Sorvis makes a major investment in the software development and IT Infrastructure establishment, as the core of the product lies in the high-tech field of predictive flow control. In addition, to develop the basis of its intelligent algorithm, Sorvis needs to pay upfront to waste sorting experts who understand optimization of the essential processes in the plants. Finally, from the legal perspective, Sorvis has to cover the company's setup fees and file for a patent to protect its process mining algorithm and AI optimization model.
Fixed Operating Costs: In this cost category, Sorvis allocates its budget between personnel costs, IT infrastructure maintenance, cloud computing usage, office rent, and R&D of new product features. Personnel costs include salaries for software developers, the project management team, and backend office employees. Since Sorvis operates a Software as a Service (SaaS) business model, IT Infrastructure, computing, and new feature R&D costs take the largest budget share. This investment ensures the high-quality performance of the solution and the constant development of new features.
Variable Operating Costs: This cost category includes marketing & sales costs, customer support center operations, sensor purchasing costs, and fees paid to subcontractors who install and set up sensors in the plant. As the goal of Sorvis to deliver a first-class customer experience, a client support center is a major cost to ensure high-
quality engagement of Sorvis employees with plant owners. Subcontracting fees also require a significant budget, as Sorvis plans to integrate sensors that require specialized contractors to install and set up. Finally, marketing and sales costs cover website establishment and online and telephonic sales as main customer acquisition tools.

Eco-Social Costs

Although Sorvis is designed to make processes more efficient there are some ecological and social costs to consider. First, to gather the relevant data for Sorvis, it is necessary to install additional sensors in the existing sorting plants. These sensors currently cannot be produced from renewable materials, which leads to high consumption of scarce resources for sensor production. In addition, not all of the sensors can be recycled that results in an increase in WEEE waste.
In addition, once the data for Sorvis is collected, it has to be analyzed. Running data mining algorithms as well as a process optimization AI model consumes a high amount of energy, which leads to a negative environmental impact unless the computer systems run on renewable energy. Apart from power concerns, process optimization comes with the risk of job cuts. Job eliminations could happen across all employee levels and departments, as Sorvis can detect inefficiencies in both business and sorting processes that could be solved by automatization.

Eco-Social Benefits

Sorvis' solution has several eco-social benefits. First, plants that implement Sorvis can optimize their power consumption compared to those not using data-driven process optimization. While running data mining algorithms requires energy, it decreases the overall power consumption of the sorting plants by adjusting the physical plant operations towards optimal efficiency. This has a positive effect on the environment since it allows the sorting industry players to save scarce energy resources.
Moreover, optimized processes lead to less plant downtime which is often caused by the wrong utilization of plant resources and plant machinery. This directly affects the amount of maintenance and repair work that needs to be done by manual workers and thereby reduces the workplace accidents that often occur in the process. As a result, manual workers get to work in a safer environment.
Finally, since Sorvis makes collecting, visualizing, and sharing data much easier for the sorting plant, it can better estimate its capacity and communicate this information transparently to the other value chain players. This communication transparency enables value chain players to adapt faster to changes in waste amount and quality, which is expected to lead to a higher amount of waste processed overall. This is a significant ecological benefit as less unsorted waste has to be landfilled or incinerated as instead waste gets sorted, recycled, and fed back into another product lifecycle.



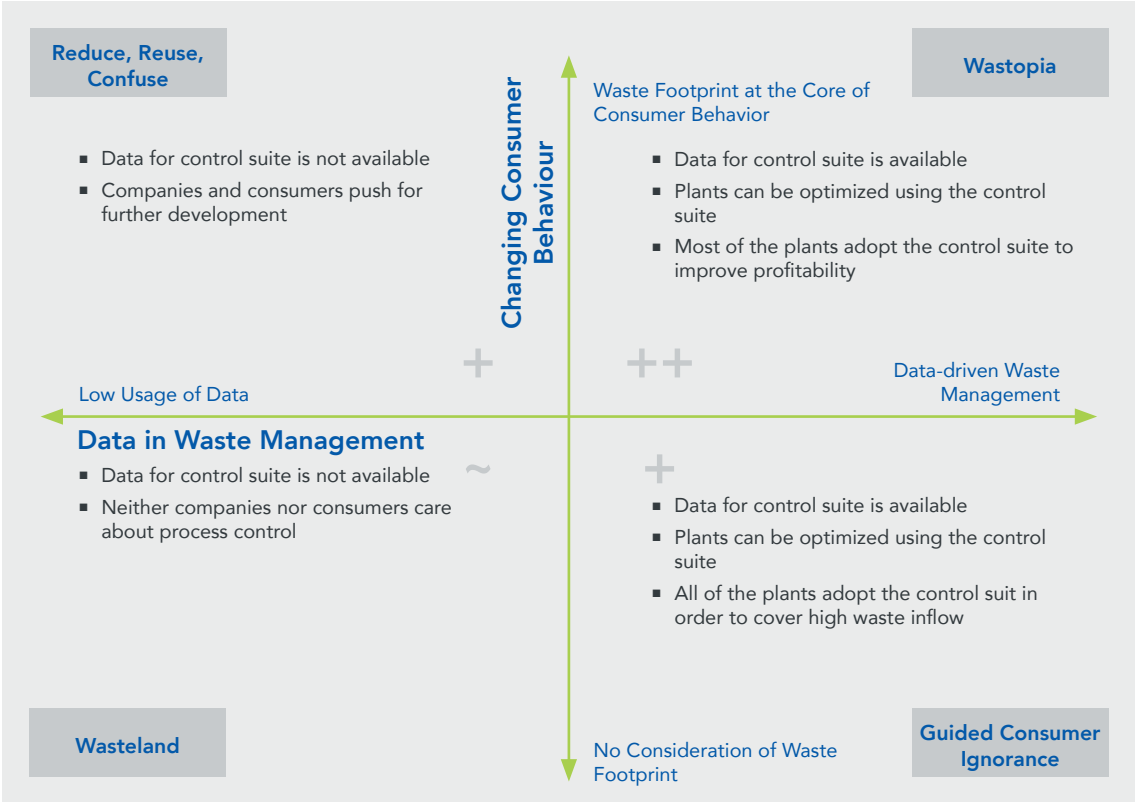
Scenario Fit

Wastopia: As in this scenario the waste management sector is data-driven and people care about the waste footprint, it is highly feasible that most plants implement plant suites to make their sorting process efficient.
In this scenario, it is proven that data-driven solutions increase the efficiency of operating the business. Therefore, most companies adopt Sorvis to streamline their plant operations and thereby increase the profitability of their business. However, as waste sorting optimization becomes highly lucrative, the market for data-driven solutions becomes increasingly competitive, so more solutions similar to Sorvis emerge. Thus, Sorvis would invest more resources into product development to ensure a strong market position.
As consumers care about their waste footprint, the waste inflow is easy to predict, and an efficient sorting plant is easier to design. Because of the predictability, most sorting plants need the same hardware structure, thus reducing the co-creation and consulting costs for Sorvis. This enables Sorvis to offer their services to a large customer base.

Reduce, Reuse, Confuse: This scenario presents the situation in which the waste management sector hardly uses any data as sensors barely exist within the waste value chain. Even though customers push for better waste management, the technological feasibility of collecting necessary data hinders the adoption of Sorvis.
As consumers and companies push towards a more sustainable waste footprint, WMS are highly requested, therefore becoming highly profitable businesses. However, companies invest their financial resources in their manual workforce to drive speed and efficiency rather than adopt technology innovations. Since Sorvis requires data gathered by sensors which are not commonly available in this scenario, plant efficiency improvements through data analysis are not feasible.
To be successful, Sorvis needs to develop process optimization solutions for the waste management sector that works with a small number of sensors. However, the business model is highly dependent on data availability, and the success of Sorvis in this scenario is uncertain.

Wasteland: In this scenario, little data availability in the waste management industry and consumers who do not consider their waste footprint create an extremely challenging environment for the adoption of a platform for data-driven decisions in sorting plants.
First, no data is available to create an in-depth understanding of the waste sorting processes to improve plants' utilization and efficiency. Second, this scenario presents a culture where consumers, companies, and government have little interest in waste management, which leads the sorting industry to be highly unprofitable and close-minded regarding technology and process innovations. Companies are required to cut costs to stay afloat, which prevents them from investing in high-tech predictive flow control systems that could enhance the plant's performance. Thus, Sorvis' solution is not adopted by the leading sorting companies in this scenario.

Guided Consumer Ignorance: With data-driven waste management and consumers who do not consider their waste footprint, the adoption of a platform for data-driven decisions in sorting plants is highly feasible.
Since most of the plants use sensors for the sorting process, the necessary data for the development of the control suite is available. Moreover, since waste management is a profitable business, companies have a budget to implement data-driven solutions. Those solutions enable more streamlined and effective processes, further increasing the sorting plants'



profit margin. The predominant digitalization of the waste management sector also creates an environment that encourages companies to experiment with high-tech solutions and adopt solutions like Sorvis.
As consumers do not care about the amount and types of waste they produce, companies have to sort an ever-increasing amount of waste. Coping with this increasing waste with the existing plant resources is an additional motivation for the plants to implement Sorvis for the process optimization. Overall, in this scenario, most of the plants use Sorvis.

Challenges

- To guarantee stable waste flow monitoring, sensors in the plants must work reliably. However, in sorting plants, sensors are exposed to dirt and mechanical friction, thus, often failing. Sorvis needs to ensure that it can provide plant operators with timely support when the sensors need to be repaired or replaced.
- Sorvis plant suite connects to the ERP, CRM, and control systems in the plant. Since sorting plants implement various vendors that differ in methods for data collection, Sorvis must be able to adapt to all systems and find a way to interconnect them into one solution. This can be solved by expanding the partner ecosystem.
- Many sorting plants are highly concerned about their data privacy, especially regarding their business processes. Sorvis needs to ensure that it strictly follows all the data regulation laws and implements high-quality cybersecurity components in the software.

Outlook

In the future, Sorvis will have a steady development journey with three focus areas - integrating new product features, expanding into the recycling plant industry, and exploring the potential of bringing hardware installation in-house, therefore eliminating subcontracting costs.
In the new feature development field, Sorvis is planning to add predictive maintenance hardware and software modules to further decrease the downtime of the machinery. Moreover, Sorvis will further enhance its offering by providing a simulation framework that predicts the effect on plant operations from adding new equipment and processes. This addition will allow plant owners to go beyond optimizing the current plant workflow.
In addition, Sorvis plans to acquire a strong network in the recycling industry through the existing client base and tailor its solution to the recycling plants with a number of similar processes to the sorting ones. Finally, as Sorvis acquires more experience and data points regarding the sensor installation and setup processes, the company will analyze the economic efficiency of using subcontractors, later potentially establishing its own team for this process. Overall, with all the planned developments, Sorvis has a great potentiern al to become a market leader in the process optimization solutions for sorting and recycling plants globally.

Leonie Wagner, Lorenz Kammer, Philipp Zinnenlauf, Richard Stromer, Sophia Escheu

DESIGNO.AI

Design for Recycling Made Simple

Designo.ai
Design for Recycling made simple.

To realize an efficient circular economy, the end-of-life handling of a product needs to be considered already at the stage of product development. Even though many manufacturing companies engage in strategies to reduce their environmental impact, explicit design for recycling still receives little attention, especially in the fashion industry. Product designers and manufacturers lack the relevant expertise to incorporate recyclability considerations in their processes without sacrificing a product's intended functional performance. Due to this, waste sorters and recyclers often cannot produce secondary materials of reasonable quality at competitive prices.

Designo.ai provides a software plugin that works with established product design tools in the fashion industry. This solution allows to rate and optimize the recyclability of products as it is fully integrated into the existing design processes. The software analyses the material composition, fastening techniques, and material shapes for potential recycling issues and impact potentials. The product designers receive feedback on the recyclability of their designs through improvement recommendations and an overall recycling score. This score enables Designo.ai to certify a product's recyclability.

At its core, Designo.ai builds on a knowledge base unifying the industry expertise of waste sorting and recycling companies with laws and legal regulations issued by governments. Close collaboration fosters more exchange across the value chain. The recommendation algorithm applies rule sets balancing the different criteria for easier to recycle products. By maximizing the recycling rates, fashion designers and manufacturers enable the circularity of their products in line with the UN SDG 12 on sustainable consumption and production patterns.

Designo.ai strives to obtain a market share of 3.4m USD within the first two years of operations out of a total addressable market of 1.9bn USD. The basic pricing plan offers entry-level access to the recommendation algorithm with limited user accounts, while the premium plan offers full access to all recommendations and the recyclability certification. A yearly subscription model generates the main revenue, and an initial setup fee adds further one-off payments. The vision of Designo.ai is to deliver the foundation for a truly circular economy by enabling customers to incorporate a product's full lifecycle into their design process.

Business Model

Key Partners

- Waste sorting and recycling companies
- Product design software providers
- Governments and legal institutions

Key Activities

- Product and recommendation engine development
- Collection and synthesis of recycling knowledge
- Acquire, onboard, and retain customers

Key Resources

- Knowledge base on recycling industry and governmental regulations
- Recyclability recommendation algorithm
- Human capital

Value Proposition

- Consumer goods companies: Optimize product design for recycling, ensure compliance with legal requirements, issue recyclability score and compliance certificates
- Waste sorting and recycling companies: Recyclable products result in high-quality secondary materials
- Industry-wide benefits: Optimize circularity of materials by maximizing recycling rates, foster exchange across the value chain, increase share of recycled materials in manufacturing processes

Customer Relationships

- Onboarding process and long-term support
- Automated customer service for operative support
- Ongoing product improvements
- Webinars and blog posts

Channels

- Online: Plugin download via a website, targeted advertising, free product trials
- Offline: Sustainability departments of potential customers, partnerships with product design software providers. Promotion via fairs and industry conferences.

Customer Segments

- Fashion design and manufacturing companies
- Product design departments
- Sustainability departments

Cost Structure

Initial investments

- Product development
- Establishment of partnerships with software providers

Fixed costs

- Personnel costs to maintain, expand, and market product
- Rent for work equipment and office space
- Fees for IT-licenses
- Financing costs

Variable costs

- Consultancy fees for experts
- Marketing costs
- Customer service costs
- Employee training

Revenue Streams

- Initial setup fee (setup, personal onboarding)
- Basic subscription fee (limited user accounts, support via chatbot and blog articles)
- Premium subscription fee (unlimited user accounts, individualized customer support and features)

Eco-Social Costs

- Impact trade-off
- Open need for reverse logistics measures
- High energy usage through server hosting

Eco-Social Benefits

- More efficient end-of-life handling
- Certification to prevent greenwashing
- Achievement of customers' sustainability targets

Value Proposition

Consumer goods companies: Designo.ai enables the product designers of consumer goods companies to consider the recyclability of new products already during the design phase. Thereby they make sure to fulfill the regulatory requirements and quotas while making a major contribution towards a circular economy in line with customer expectations. Designo.ai provides these guidelines directly in the established software tools that product designers already use on a daily basis via plugins. In the background, there is an extensive knowledge base to answer any potential question, which allows designers to understand more deeply how they can contribute and what impact can be achieved. After the designs are finished, Designo.ai provides certificates on the product's recyclability score for regulators and customers, as well as data sheets on material compositions, mixtures, and manufacturing processes to be forwarded to recyclers and waste sorting companies. Overall, the tool allows to define, realize and measure product-related recyclability targets across the whole company.

Waste sorting and recycling companies: The improved recycling characteristics of products designed with Designo.ai benefit waste sorting and recycling companies. Their recycling processes can be simplified as better-designed products consist of more homogeneous materials and are combined in an easy to disassemble way. After recycling, the resulting secondary materials are purer and of higher quality, increasing profits for recyclers. These efficiency gains lead to clear cost savings and thus improve the economics of the industry. Close collaboration and knowledge exchange will enable them to influence upcoming product designs to a certain degree, making sure products are properly recycled.

Industry-wide benefits: In addition to individual stakeholders, the industry and the environment overall benefit from Designo.ai through a decreased virgin material extraction. The software optimizes the circularity of materials by maximizing recycling rates. The collaboration fosters exchange between so far disconnected stakeholders across the whole value chain. Overall this opens the path for an increased share of recycled materials in the manufacturing processes of products.

Customer Segmentst

Fashion design and manufacturing companies depict the targeted customer group as they face increasing public pressure to bring eco-friendly designed products to the market. This pressure within the fashion industry arises from rapid release cycles, low recovery and recycling rates, predominant usage of virgin materials, environmentally damaging production processes, and, first and foremost, an increasingly sustainability-focused customer base. In this context, Designo.ai's software solution can address small and big players within the fashion industry. Despite the features' appeal to corporations of any size, the product is of the greatest value to companies with complex, multi-stakeholder product design processes in which designing for recycling cannot be easily incorporated. Although these larger corporations require a longer sales cycle, they are most attractive as they provide a higher margin and deal size, which justifies the sales team's efforts. Based upon the fact that Designo.ai is a product tailor-made for and used by fashion design teams, an initial focus on team collaboration with many contributors to be onboarded at once allows scaling the software faster and more effectively. An additional important stakeholder represents the sustainability departments of these corporations: Their task to ensure and improve a corporation's environmental impact on society requires them to identify and introduce ecological footprint enhancing products like Designo.ai. Here, especially the ability of Designo.ai to provide recyclability certificates supports them in realizing their objectives.

Customer Relationships

Onboarding process and long-term support: Designo.ai offers its customers a comprehensive and personal onboarding process. A customer's initial experience defines their ongoing relationship with a SaaS business, that's why Designo.ai needs to assist new users as much as possible during the first couple of weeks. To accomplish this, each customer is assigned an individual customer success agent from day one, who ensures smooth operations for the customer.

Automated customer service for operative support: A dedicated chatbot provides 24/7 assistance to users during the design process. This automated customer service based on AI addresses frequently asked questions and allows Designo.ai to serve a high number of customers in a short amount of time. Additionally, it is incorporated directly into the plugin. Customers who choose a Premium plan can reach Designo.ai's service hotline for more personalized support.

Ongoing product improvement: As a result of customer feedback received through customer success agents and customer service chatbots, Designo.ai continuously adjusts its features, the UI/UX Design, and customer support processes. Further, this extensive feedback collection mechanism allows Designo.ai to stay abreast of new technological innovations in the recycling and design industries. Designo.ai establishes a relationship of mutual empowerment with its customers through this co-creation process.

Webinars and blog posts: As a means of cultivating an engaged customer relationship, Designo.ai publishes blog articles and holds regular webinars to educate and train its users. In this way, Designo.ai ensures customers can maximize their benefits while using the software plugin and perceive Designo.ai as a strong knowledge partner they can leverage to advance their understanding of product recyclability.

Channels

Online: Due to the digital nature of Designo.ai's product, online channels play a significant role in customer acquisition and retention. The company's website is the centralized point of contact with future customers. There they can find the first information, create an account, and download the plugin tool immediately. Potential customers are directed to the Designo.ai website via SEO and targeted advertisements on social media. Fashion-related online magazines, forums, and blogs that appeal primarily to the target group of product designers will also be used to generate awareness and increase Designo.ai's customer reach. Designo.ai offers a free 4-week trial period which allows potential customers to test the basic product features before subscribing to a paid plan. This enables potential customers to learn about the product's characteristics and experience its value themselves.

Offline: In addition to using online channels to gain customer traction, Designo.ai also focuses on several offline channels to further position itself in the sustainability and consumer product design markets. Sustainability and CSR departments will be leveraged as the first touchpoint with customer companies to discuss product-related recyclability targets and to

identify the impact that the Designo.ai software can achieve. Partnerships with traditional software providers within the product design industry will be a key channel to gain access to potential customers. The product is also promoted at fairs and industry conferences to reach the right contact persons within these departments. Furthermore, this has the advantage to directly engage with potential customer companies about their problems and needs. Designo.ai additionally aims to use university partnerships to equip design students with the relevant knowledge about its plugin from early on.

Key Activities

Product and recommendation engine development: Building, maintaining, and improving the design for recycling software is the center of Designo.ai's business activities. The product consists of three software components: The plugins for product design tools, the recyclability recommendation algorithm utilizing machine learning models, and the underlying infrastructure that includes the database. After the initial concept and setup phase resulting in an MVP for each component, those need to be further defined and continuously improved based on customer needs. The database layout and setup are essential to model and store all the rules and information. Based on this data, the engineers and data scientists train and test the machine learning models employed in the recommendation engine. The so far described backend provides a universal API to be used in the individual plugins for each design tool.

Collection and synthesizing of recycling knowledge: Based on continuous expert interviews with waste sorting and recycling companies, Designo.ai creates a profound knowledge base on sorting and recycling best practices. It is important to collect a vast but detailed amount of information on the recyclability of material types, compositions, combinations, product shapes, and local waste management systems and processes.

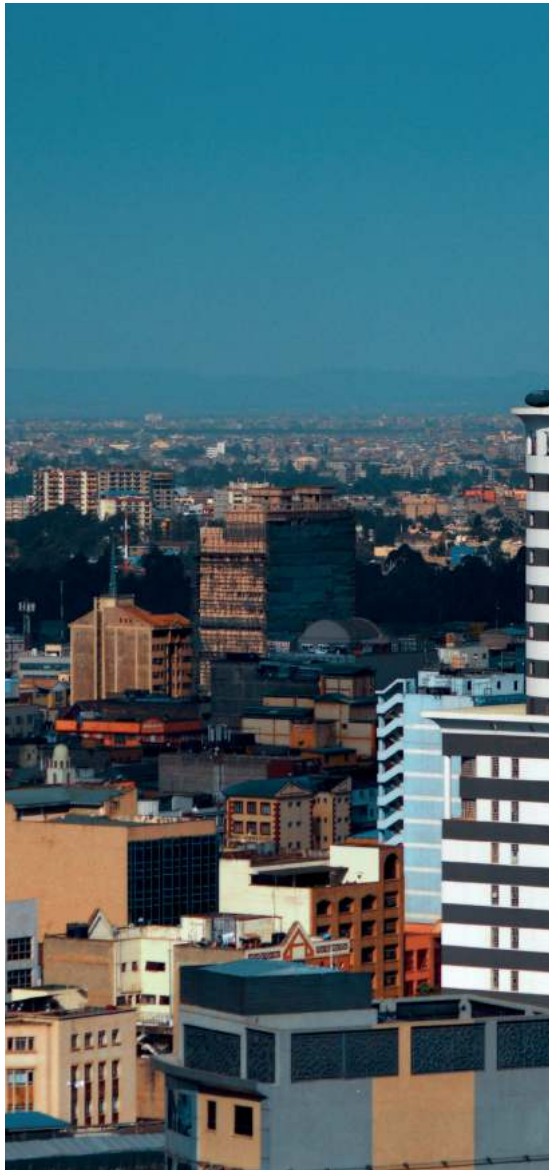
Acquire, onboard, and retain customers: Winning the first pilot customers is essential to validate the business idea and generate first revenue. The brand of Designo.ai needs to be established in the market through marketing and advertising in the relevant channels. Further, keeping a good customer relationship is essential to retain customers and continuously grow the customer base. Designo.ai aims to accomplish this through a holistic and personal onboarding process and ongoing support through customer service and success agents. Within these processes, the sales and customer success teams generate insights about the customer's needs and problems. Later this information enables further product improvements and provides new customers with a streamlined onboarding experience to the tooling.

Key Resources

Knowledge base: To create a comprehensive knowledge base on product recyclability, it is highly relevant to collect information on individual material characteristics and fastening techniques that result in material recycling losses and contaminations. Based on the database, product recyclability challenges can then be identified. Additionally, understanding optimal sortable and recyclable material combinations and product shapes in the fashion industry is necessary to provide customers with recyclability improvement recommendations. These keep a product's intended performance quality. This holistic data resource enables Designo.ai further to give a recyclability score for all products of its premium customers. With a recycling certificate, Designo.ai verifies the reached recyclability score and thus provides transparency on how well a product can be recycled.

Recyclability recommendation algorithm: The proprietary proactive recyclability recommendation algorithm represents a core competitive advantage of Designo.ai and is the fundamental feature of its software. The algorithm incorporates design preferences and required product characteristics to overcome the identified recyclability challenges. It can pinpoint design issues, prioritize different possible design adjustments that can be implemented, and maximize resource efficiency.

Human capital: Competent tech and business employees are required to build and market the software plugin. Data engineers develop and maintain an infrastructure to collect data on customers' fashion product designs and optimal recyclable product materials. Experienced data scientists leverage this infrastructure to build AI based algorithms that identify recyclability challenges and recommend underlying design optimizations. Therefore, data scientists need to train, test and deploy the most accurate algorithms. Software developers set up, extend, and maintain a plugin that integrates



the deployed algorithms into commonly used product design software. Additionally, sales agents convince new customers to integrate the product into their existing design processes. In parallel, customer success agents support existing customers in rolling out the standard software and realizing individualized feature adoptions and new feature development.

Key Partners

Waste sorting and recycling companies: It is key to integrate the industry knowledge of sorting and recycling companies early on into the software development process of Designo.ai. Their expertise is especially valuable to understand how to design products that are recyclable in theory and practice. In return, sorters and recyclers require information on the materials used and how to separate those. A close partnership with the industry allows Designo.ai to develop a recommendation algorithm based on real-life conditions. It ensures that products are properly sorted, recycled, and their materials reused.

Product design software providers: The cooperation with established software providers for product design ensures seamless technical integration of the plugin with their systems and adds value for both sides. On the one hand, the Designo.ai plugin adds new functionality desired by customers beyond the original software's features for the software partners. On the other hand, Designo.ai depends on its software as a platform for easy integration into a designer's current workflow. Therefore, a close collaboration ensures proper functionality and tight integration of the Designo.ai plugin resulting in a superb user experience (UX).

Governments and legal institutions: Authorities, such as the EU, continuously release new regulations defining product design and recycling requirements. To ensure customers' compliance with these regulatory guidelines, Designo.ai must align the product closely with legislators, stay up-to-date about upcoming changes, and keep the recommendation engine legally compliant. Furthermore, a strong partnership with governments regarding the accreditation of Designo.ai's recyclability certificates can strengthen the market positioning of the Designo.ai software enormously.

Revenue Streams

Designo.ai follows a monthly subscription model that is supplemented with an initial setup fee. The subscription model is divided into a basic product with limited standardized software features and a premium product with extended individualized software features. This offering allows targeting small to medium as well as larger customers with a company-specific product offering.

Setup: Every new customer that signs up has to pay an initial setup fee. This installation incorporates the integration of the software plugin into existing design tools and an extensive onboarding session for the design and the sustainability department.

Basic subscription: The basic subscription plan limits the number of user accounts to a maximum of five designers. Customers can only rely on automated customer support through chatbots and blog articles that answer the most frequently asked questions. The product's core competitive advantage, the recyclability recommendation system, is available to a limited extent by only improving material composition.

Premium subscription: The premium subscription offers highly customized customer service combined with an extended feature set. An unlimited number of designers can use not only a chatbot and blog articles but also customer support agents to address questions. In addition, a dedicated customer success agent identifies and introduces individualized software advancements in collaboration with the customer's product design department. This customer-specific contact person also trains individual designers in optimally using Designo.ai, thereby increasing their products' recyclability. Moreover, the recyclability recommendation system becomes available to its full extent and therefore recommends improvements along with product shapes, material compositions, and fastening techniques. Lastly, the issuance of certificates for ideally recyclable products provides customers with the unique opportunity to address customers with an above-average willingness to pay in a strongly emerging sustainable product market.

Cost Structure

Initial investment costs: Before launching a functional product, the foundation of Designo.ai is dependent on initial investments for product development, the establishment of core partnerships, and knowledge building within the design for recycling domain. Firstly, the recruitment and salaries of tech staff, i.e., data engineers and scientists, and software developers, represent a major cost component. Secondly, establishing partnerships with product design software providers is essential to test and promote the product in industry-wide used design tools from early on. Lastly, costs occur to build up the knowledge database with recycling experts. Additional legal fees to register the company and validate the recyclability certification process supplement this cost position.

Fixed costs: Once Designo.ai goes live, personnel costs make up the majority. Business teams with strong marketing and sales expertise acquire and onboard new customers. In addition, a business development team identifies new product advancements. In this context, tech teams maintain the existing product, optimize the underlying algorithm and continuously implement the newly derived product features and application areas. An additional fixed cost position arises from the rent of office space and work equipment. Further, licensing fees for cloud-hosting and database services are essential to run the technical infrastructure. Lastly, financing costs for the obtained initial investments need to be considered.

Variable costs: Variable costs include the consulting fees of recycling and legal experts. Due to the onboarding process of new customers and ongoing product advancements, continuous knowledge exchange is necessary. Besides overtaking high variable costs, raising awareness for consumer goods across the derived sales channels requires dedicated marketing activities. Customer-specific service costs and employee training complement the variable cost positions.

Eco-Social Costs

Impact trade-offs: Often, a certain material or adhesive comes with a range of benefits that enable easier sorting, dismantling, and recovery. However, specific materials or production processes may score low on impact measures, such as environmental pollution or human rights compliance. What is beneficial for recycling, therefore, is not always the most sustainable choice in every dimension. Thus, Designo.ai aims to extend its offering from only optimizing for end-of-life handling to a more holistic view of sustainable production. In addition, Designo.ai works closely with their customers during the onboarding process and beyond to define individual impact strategies.

Need for reverse logistics measures: When designing a product for optimized end-of-life handling, it is possible to be recycled if it is disposed of in the right way, collected, and the right sorting and recycling infrastructure is in place. In current waste management operations, this is often not the case despite a responsible design. This results from a lack of consumer education, low producer responsibility beyond the first sale, differences in regional waste management systems, and the varying financial viability of recycling operations. Enabling consumer goods companies to design recycle-friendly products easily decreases the pressure to extend a product's life cycle through holistic take-back schemes that allow reuse or repair. Especially, the promotion of technically recyclable products may result in consumers that deem their sustainability requirements as fulfilled and continue buying new products from manufacturers. That way, the preferred options of the waste-hierarchy to decrease the environmental impact of waste, namely reduce and reuse, may stay unaddressed or even neglected.

High energy usage through server hosting: A computational powerful server infrastructure is necessary to continuously train, test, and deploy the recyclability recommendation algorithm with its machine learning algorithms. Furthermore, another server cluster containing a large database that stores all the relevant input information along the full product value chain is required. Continuous operation, maintenance, and cooling consume a significant amount of energy and cause additional emissions.

Eco-Social Benefits

More efficient end-of-life handling: To successfully introduce a circular economy in industries, products must be dismantlable, and it is necessary to recycle product components after their use. By implementing a designing-for-recycling process, designers already include end-of-life considerations in the product's early life cycle stage. Those efforts minimize the number of disruptions during the sorting and recycling processes from very early on. Overall, this translates into higher economic incentives for recyclers on the one hand and the generation of a large amount of high-quality recycled material that is used as secondary raw materials on the other hand. Designo.ai supports customers to transform their existing linear material lifecycle into a circular one by increasing the recyclability of their products. Thereby, upcycling rates and scare materials recovery rates are increased.

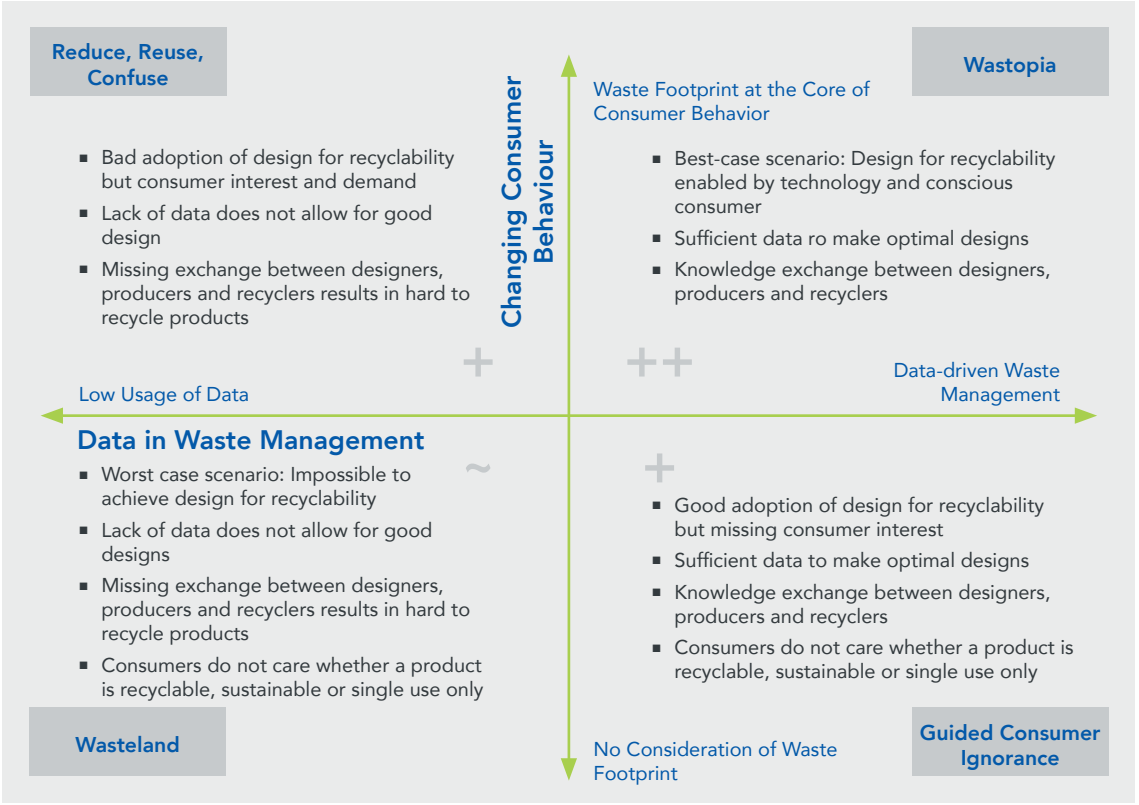
Certification to prevent greenwashing: Products are often marketed as sustainable or green but the exact meaning is not transparent to the consumer. By offering a recyclability rating score, Designo.ai ensures the missing transparency towards a company's end customers. The recyclability score is derived based on a thorough analysis of recyclability guidelines developed together with experts. Its calculation can be made publicly available via a QR code on a product's price tag. This empowers consumers to understand a company's recyclability efforts fully and therefore make a conscious purchasing decision.

Achievement of sustainability targets: Sustainable production, as described in the UN SDG 12, is one of the fundamental drivers of the sustainability strategies of many consumer goods companies around the world. Companies strive to use their input raw materials efficiently, reduce the waste produced through their product sales, and include the measures they take to achieve this in their reporting cycles. By introducing Designo.ai in design processes, companies can first continuously improve their product designs towards more efficient resource management and, second, analyze and report the achieved ecological impact.

Scenario Fit

Wastopia:
This scenario combines the best of both worlds for Designo.ai. On the one hand, the availability of data will empower the company to make optimal design suggestions for customers based on the company's sophisticated knowledge database. Moreover, data-driven waste management will enable the knowledge exchange between designers, producers, and recyclers. This collaboration will both foster, and improve the UX of Designo.ai for customers as they will benefit from holistic, integrated knowledge about recyclability in product design. On the other hand, consumers who are conscious about their waste footprint present a powerful lever for Designo.ai. These consumers value sustainability and will therefore put pressure on companies to provide recyclable products. Hence companies will face strong pressure to incorporate tools like Designo.ai in their product design process.

Reduce, Reuse, Confuse:
In this scenario, the lack of data presents a major challenge to Designo.ai. First, good design recommendations are dependent on data. Without sufficient knowledge about



optimal sortable and recyclable material compositions, fastening techniques, and product shapes in the fashion industry, it will be challenging to provide customers with decent recyclability improvement recommendations. Second, the missing exchange between designers, producers, and recyclers will further complicate this problem. Most likely, this fragmented landscape of key players will result in products that are hard to recycle. On a positive note, consumers will still value sustainability and demand recyclable products. However, it will be hard for Designo.ai to provide customers with the promised value propositions without sufficient data. Therefore, it remains difficult for customers like big fashion designers and manufacturers to deliver on the consumers' demand for sustainability.

Wasteland:
This scenario presents the worst-case scenario for Designo.ai. The feasibility of the software to function properly is limited, as sufficient data on the optimal recyclability of products is lacking or not shared among players in the waste management industry. Therefore, it will be challenging for Designo.ai to identify issues in the recyclability of products and retrieve underlying data-driven recyclability improvements. To further complicate the situation, end-consumers do not consider sustainability as an important purchasing criterion and therefore do not care whether a product is recyclable or single-use only. Hence, they will not impose extensive pressure on fashion companies to design more recyclable products. Consequently, fashion companies will have little incentive to spend money on sustainability efforts. The developed business model of Designo.ai will probably not be feasible in this scenario.

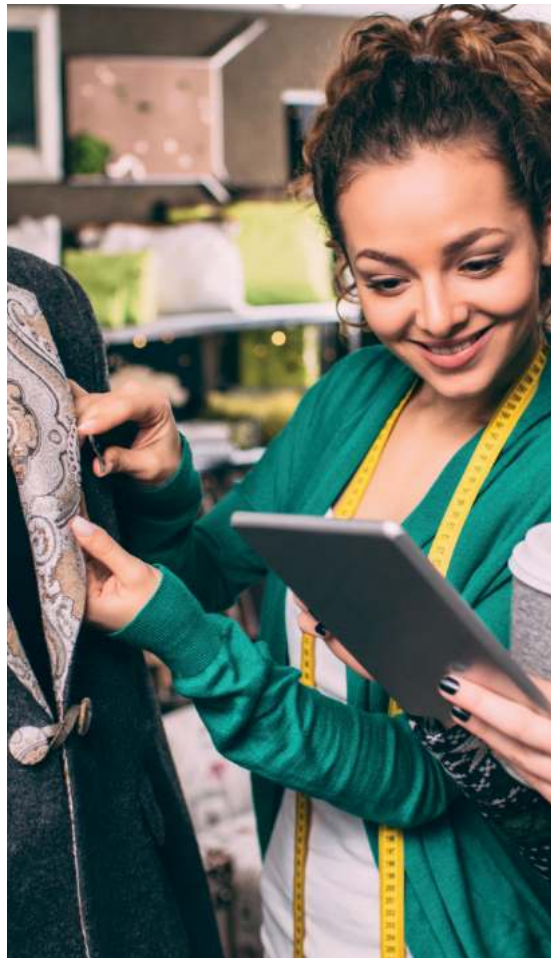
Guided Consumer Ignorance:
In the last scenario, the large availability of data throughout a product's value chain will make Designo.ai feasible from a technical point of view. The extensive database, especially from sorting and recycling processes, will allow Designo.ai to develop optimal designs for customer companies. Driven by the significant value of secondary materials, consumer goods companies across many industries have an intrinsic interest in designing their products for recycling and investing in their materials' circularity. Additionally, the knowledge exchange among key players such as designers, producers, and recyclers will further enforce this trend. However, the challenge comes from a commercial point of view. Consumers do not care whether a product is recyclable, sustainable, or single-use only.

Challenges

- The overall product design process is highly complex and includes a variety of stakeholders in iterating process loops. Therefore, Designo.ai needs to be usable and integrated throughout the whole design process.
- Determining the best recyclability recommendation can be inconclusive and difficult. Even within an industry, the recycling methods for products can vary. Depending on the product, it is often impossible to immediately assess the improvements in recyclability standalone. A closer examination of the holistic product manufacturing and waste management process is necessary.
- Currently, designers rely on a broad spectrum of design software. The Designo.ai plugin must be integrated into different software, ranging from tablet apps to sophisticated 3D modeling software on desktop computers. In particular, the integration must be seamless, so the entire design process is not complexified.
- The database for training purposes of the recommendation algorithm needs to comply with data privacy regulations to avoid the leakage of customer-specific design approaches which is the core competitive advantage of a player in the fashion industry.

Outlook

Designo.ai aims to enable customers across several consumer goods industries to design for recycling. The primary goal is to integrate complex recyclability requirements as smoothly as possible in current product design processes. Secondly, Designo.ai aims to establish itself as a strong and competent knowledge partner for its customers. The software is going to be a key enabler for customers to meet recycling targets in line with their legally binding EPR. Given that recyclability specifications vary from industry to industry, Designo.ai will initially focus on the fashion industry. The fashion industry is under pressure to put eco-friendly products on the market, thus making it the ideal pilot industry for Designo.ai. This focus is going to allow the company to achieve its first product-market fit and advance product features step by step. Next, Designo.ai aims to extend its product offering to the packaging sector, with similar challenges and characteristics. On a product side, Designo.ai plans to expand its features to foster an overall positive environmental and social performance throughout the value chain, including material extraction, production, and reverse logistics. Internationalization beyond German borders will further drive the company's growth prospects.



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THE FUTURE OF WASTE MANAGEMENT

What does the future hold for waste management? While the demand for a pollution-free environment for humans has never decreased, the amount of waste produced over the past decades has significantly risen. Digital solutions and services have introduced a whole new universe of waste management possibilities, also carrying their own problems such as cost, reliability, and privacy concerns.

How can we best deal with all the trash we produce? How will we recycle our waste and reuse or repair products in the future? How will legislation influence product design and repairability? How can we improve our consumption and recycling habits in our everyday lives?

New ways of managing our waste and rethinking how we consume and produce products hold promising opportunities in balancing our needs and the ones of the planet. However, various uncertainties will decide how the future will unfold. What benefits will advancing technologies such as artificial intelligence, robotics, or smart sensors bring to recycling and waste management systems?

This report looks into these questions and explains how waste management will look in twenty years. It identifies current trends (political, economical, social, technological, environmental, and legal) that affect the future of waste management and derives four scenarios and five related business ideas. The generated business concepts range from a modular trailer to assist trash collectors in Africa, a new modular trash chute, an X-Ray machine for sorting plants, an innovative plant monitoring tool, to software aiding designers to make sustainable choices already in the design process.

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The Center for Digital Technology and Management (CDTM) is a joint interdisciplinary institution of education, research, and entrepreneurship of the Ludwig-Maximilians-University (LMU) and the Technical University of Munich (TUM).

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