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Assignment 3E

Report

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Contents

1 Abstract

The project work for the United Nations' Sustainable Development Goal 12 emphasizes the challenges of managing e-waste as technology becomes increasingly integral to daily life. Frequent updates of electronic devices, from smartphones to electric vehicles, exacerbate the e-waste problem, particularly due to the environmental impact and recyclability of batteries and solar panels. Effective e-waste management requires new strategies such as increasing collection points, implementing new tracking systems, education, and strengthening legislation. These approaches enhance traceability, improve recycling efficiency, and promote sustainable practices. By adopting these measures, we can better manage e-waste and reduce the environmental impact.

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2 Introduction

The United Nations' Sustainable Development Goal 12 (SDG-12), which focuses on responsible production and consumption, among other things, emphasizes how difficult it is to manage e-waste, especially as technology gets more and more integrated into our daily lives. This particular problem is made worse by the regular update cycles of electronic gadgets, which include anything from smartphones to electric vehicles (EVs) and greatly contribute to the e-waste issue. Notably, batteries present a special problem because they power a wide range of devices, from large electric cars to tiny smartwatch cells. An additional level of complexity is created by the environmental impact and recyclable nature of primary (single-use) batteries (Baldé et al.. 2024).

The problem of e-waste is made worse by the increasing integration of electronic components into legacy products and items as a result of technological advancements. Furthermore, even though solar panels have a long lifespan—many decades—when their useful lives are coming to an end, they pose a new recycling difficulty. (Baldé et al.. 2024)

Reducing e-waste requires reliable tracking systems that guarantee effective collection and separation, especially for batteries and solar panels. Strong traceability programs are important to improve recycling, reduce environmental damage, and support environmentally friendly production methods. With improvements in this field, people could better manage the lifecycle of these electronic devices and their components, ensuring that these items are correctly recycled and that their environmental impact is kept to a minimum. By encouraging a more sustainable relationship with technology, enabling the increase of the recycling rate of devices, and reducing the harmful effects of e-waste on the environment, this strategy is in line with the more general objectives of SDG-12.

3 Development Approach

Design Thinking

Service design is a multidisciplinary approach that combines tools and methods, a new way of thinking rather than a new academic field. However, service design is still in its infancy, as there is currently no agreed-upon definition or comprehensive terminology for the field (Stickdorn, 2011).

Creating thoughtful experiences via the use of both tangible and ethereal media is the aim of the emerging field of service design. Use in retail, finance, transportation, and healthcare, for example, significantly enhances the end customer experience. (Stickdorn, 2011)

Five principles of service design thinking are as under:

1) User-centric - It is important to view services from the perspective of the end user. Services cannot be treated as an inventory item, as they are not physical or standardized products. Instead, the exchange between a service provider and a customer creates the service experience, which has to be user-centric.

2) Co-creative - Involving all stakeholders in the service design process is important. When a service design process places the customer at its heart, it means acknowledging that there may be multiple customer groups, each with distinct wants and expectations.

3) Sequencing - An order of connected operations should be used to visualise the service. Services are cyclical, dynamic processes that happen over time. Customers' moods are influenced by a service's rhythm, hence it is imperative to take this service timetable into account while building services.

4) Evidencing - Physical artifacts should be used to visualize intangible services. Services, such as hotel housekeeping, frequently happen in the background and go unnoticed. These kinds of services are actually purposefully made to be unnoticeable. But if a customer only learns about these behind-the-scenes procedures when they pay a bill, their lack of conspicuousness could cause a gap in their expectations and possibly lead to a breakdown in their satisfaction with the service.

5) Holistic - One should take into account a service's overall environment. Despite being intangible, services are typically associated with some sort of concrete result and occur in a physical setting with physical artifacts. Customers subconsciously take in these surroundings through all of their senses. When services are physically manifested, we can see, hear, smell, touch, and taste them. (Stickdorn, 2011)

Service Design

As a component of design inquiry, service design has been presented as a human-centered and creative approach to service innovation (Eun, 2014). In one of the first descriptions of the topic, service design is defined as "planning and shaping useful, usable, desirable, effective and efficient service experiences". (Moritz, 2009). However, due to its dynamic nature, service design is now better understood at a higher level of abstraction rather than providing a limited explanation of specific design tasks. Put another way, service design is increasingly recognized as an "approach" or "way of thinking" that may be utilized with a variety of service innovation techniques. (Stickdorn, 2011).

Sprint Methodology

Good concepts are hard to come by. And the road to practical achievement is not always clear even for the best ideas. That holds true whether an individual works for a big company, runs a startup, or teaches classes. It can be challenging to execute. Where should one direct their efforts the greatest, and where should one begin? How will the concept appear in practice? Should the entire team come up with ideas, or just one bright person be given the task of solving it? And how can one determine which answer is the best? How many consultations and meetings are necessary to reach a conclusion? And will anyone care when it's over?

Startups have a superpower thanks to the sprint: they can preview their near-final product and client feedback well in advance of making any costly commitments. The payout is enormous when a bold concept wins a sprint. However, even though they hurt, failures offer the best return on investment. Being able to find important errors after only five days of labor is the pinnacle of productivity. Without the "hard way," it's learning the hard way. (Knapp et al. 2016)

The sprint is a special five-day procedure that uses customer testing and prototyping to address important concerns. It's the "greatest hits" of design, innovation, behavioral research, corporate strategy, and more, all neatly assembled into a systematic process that can be used by any team. (Knapp et al. 2016)

Overview of Sprint Process

The overall idea of the book is to provide the readers with a guide for running their own sprint to answer the pressing business questions within five days. The sprint starts on Monday and ends on Friday. It is very important to start the sprint on Monday, so as to maintain the continuity of the work without any gaps like weekends. On Monday, the problems will be mapped out and also an important place that needs to be focused will be picked up. On Tuesday, solutions need to be sketched on the paper. The difficult tasks of making decisions will be made on Wednesday, and then those ideas will be converted into a hypothesis. On Thursday, a prototype that is realistic will be built for testing with real humans on Friday. Figure 1 depicts the flow followed in the Sprint.

The authors of the book being experts in conducting sprints, try to help the readers assemble the perfect team to conduct sprints. The main idea is not to come up with a complete, elaborated, ready-to-ship end product, but to make quick progress and check whether the team is heading in the right direction. The book also advises not to be afraid to take a gamble, as there is always a chance to succeed. (Knapp, 2016)

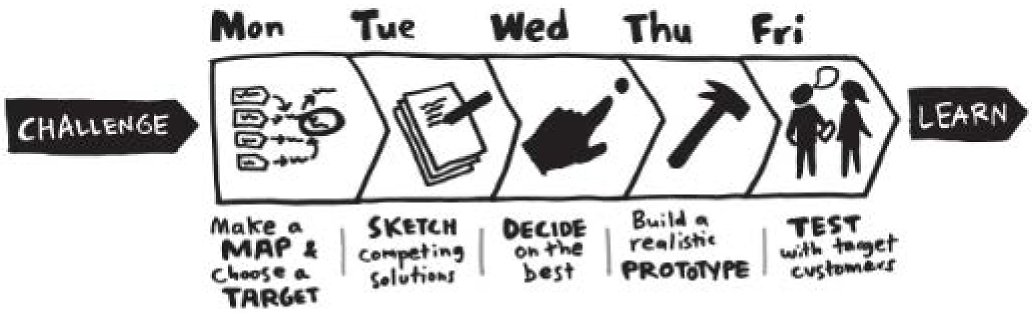

Figure 1: The Sprint Flow. Sprint How To Solve Big Problems And Test New Ideas In Just Five Days (Knapp et al. 2016).

During the coursework, the team kept the design sprint method in mind when preparing for the intensive week in Geneva, but of course, utilized other service design methods and approaches that are detailed in the next section.

4 Evolution of the Design

In this part of the project report, we will discuss how the team approached the problem from the initial member selection and group formation, until the final solution. The following pages will highlight the design process, the phases, the tools and methods used, as well as mention the evaluation criteria for the ATTRACT technologies.

The content will be divided into four sections, following the timeline of the work: before the bootcamp kickoff, during the kickoff event, teamwork between the kickoff and the bootcamp, and the effort done in Geneva.

As it will be made clear in the coming section, the team used a wide array of service design methods, sometimes knowingly, other times unknowingly. These methods helped the team to foster progress and to create alignment in topics where the team members had diverse opinions or where they momentarily got stuck.

4.1 Individual preparations

To prepare for the bootcamp and get familiarized with some of the service design frameworks, one of the pre-assignments required the group to read the Sprint book by Knapp, Zeratsky. and Kowitz (2016).

The literature provided a good framework and expectation setting on what the team will experience going forward. The concept of “design sprint” covered what it is like for a team to work together during an intense week and to figure out a solution to a problem that could also be tested in a short timeframe.
Beyond the broad concept seen in Figure 2, the book also gave brief insights into individual service design techniques, such as interviewing experts, sketching prototypes, and guiding the team in decision-making.

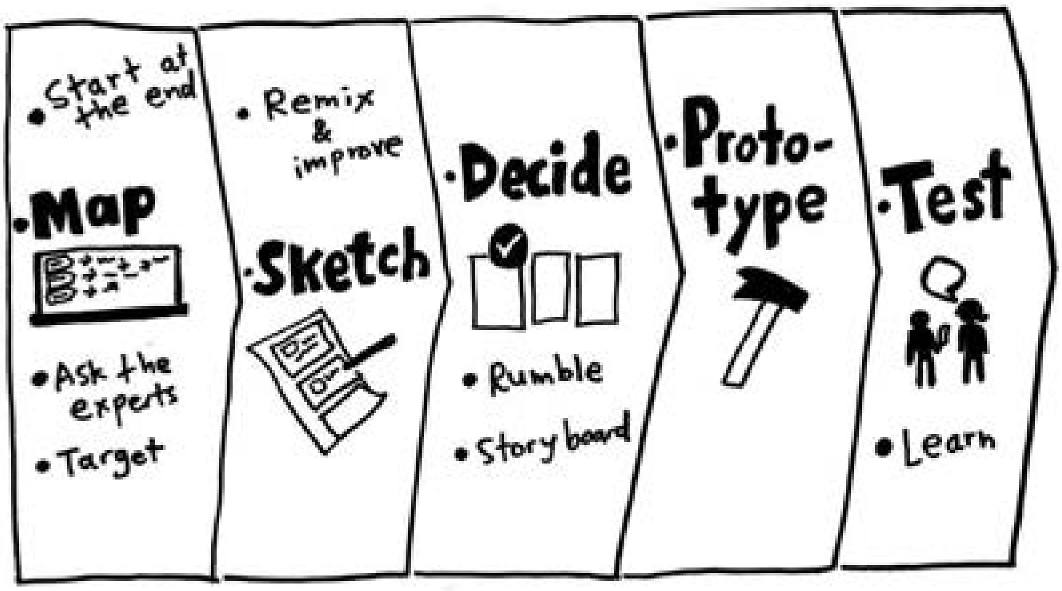

Figure 2: The illustration of the design sprint process (Knapp et al. 2016).

After familiarizing ourselves with these core concepts, the students who signed up for the bootcamp were excited to meet each other at the kickoff.

4.2 Bootcamp Kickoff

During the two-day event at the University of Helsinki, the organizers ensured that beyond getting to know the project participants, everyone had a sense of the broad problem area, got in touch with the selected ATTRACT technologies, and had virtual sessions with some of the CERN staff who will be guiding the teams in person.

While many of us already had some exposure to the United Nations' Sustainable Development Goals (SDG), the team got more familiar of the topic with the help of a world café session, where we discussed the issues in multiple rounds, rotating around tables and talking through our views.

During the kickoff event, the team selected SDG-12 as its focus area, which is about responsible consumption and production. The United Nations has 11 targets (The Global Goals s.a.) for this goal, including reducing food waste, reducing waste generation, as well as promoting sustainable procurement practices. Most of the targets were aimed at creating a circular economy, one where the society is closing its gap to reuse 100% of the materials produced for long-term sustainability.

SDG-12 proved to be a gigantic problem area with many challenges to solve, so it took quite some time for our team to narrow down the scope of the problem that we wanted to address. Our very first exercise together was sort of a brainwriting, where team members silently captured their ideas on what could be our problem candidates, discussing and grouping the topics. After the grouping, we utilized dot-voting to see what areas were more popular in the group (see Figure 3), indicating where to put our focus as we continue.

Figure 3: Initial ideation for the SDG-12 problem areas that the group could focus on, including the team’s very first dot-voting (team-created photo).

Our team ended up being quite small and nimble, only containing four members, which was both advantage and disadvantage at times. This team size was helpful in later stages where we needed to find a fitting meeting time or just having to survey the group about our opinions. In contrast, the team size made it sometimes difficult to distribute work well, as each of us had its own commitments outside of this course.

Luckily, the diverse backgrounds helped us focus on the selected challenge from various perspectives. Two of the team members, Sunil and Nitish, were from India and had a construction management background. In addition, Joanna is a British-Finnish citizen with experience in content creation, and András is a Hungarian national now living in Finland, studying business transformation.

With the two-day bootcamp kickoff concluding, the team agreed to schedule its next meeting a week from then, to discuss how we want the team to operate, including meeting frequency and rules of engagement.

4.3 Preparing for the Bootcamp after the Kickoff

When the teamwork really started to kick off, we all knew that we were not the experts on circular economy, so we needed a framework that helped us explore the topic. Our choice was to go with Design Council's Double Diamond methodology (Design Council s.a.), which breaks down the problem and the solution areas into Discover, Define, Develop, and Deliver stages. According to the concept, first, we needed to collect more insights about the problem, so we decided to do quantitative and qualitative research.

This early discussion with the team was very interesting, as we were in parallel learning about a new topic while deciding to narrow down the problem area based on what we just learned.

To get ourselves more educated about Sustainable Development Goal 12, we first did desk research, collecting information and data figures from public websites, from literature, and from different companies' various initiatives. As might be visible in Figure 3, the team was initially interested in food waste, plastics, and recycling, so we wanted to know more about the challenges in each area, what solutions there are today, and what might still be missing. We had an understanding that each of these areas is very broad, and if we want to find a good solution, we should dive deeper into a subtopic versus just providing a high-level solution for a general problem.

During the desk research, we discussed our findings in several online meetings, conducting a co-creation workshop where we could build on top of each other's ideas to get to a conclusion. As part of this research, we also mapped out the customer journey of an average customer, what steps they face when they want to recycle an item, and what difficulties we could eventually address. The online discussions were mainly assisted by a continuously updated team document (agenda, notes, proposals, etc.) and a Miro board that is visible in Figure 4.

Figure 4: Screenshot of the team’s visual collaboration (Miro 2024).

To support our data and desk research with quantitative insights, we conducted three expert interviews and discussed with three ATTRACT technology providers.

The team discussed with experts at the VTT Technical Research Centre of Finland, The Recycling Industries of Finland association (Kierrätysteollisuus), and Paristokierrätys, a battery recycling organization. Altogether, we involved 5 professionals in these interviews, who were able to provide more context to our challenge, as well as explain where the industry is heading, what happens in the regulatory environment, and what challenges might still be unsolved.

In terms of ATTRACT technologies, we identified that RandomPower, H-Cube, and Sniffdrone could be suitable for our problem area while acknowledging that we will not know how suitable these technologies are until we have an idea of our final solution. Our team discussed with these providers to get more information on the technology than what is available online, share some of the problems and ideas the group had at that point, and collectively brainstorm with the partners on potential use cases. When narrowing down the problem area, we concluded that RandomPower could be a good candidate for the solution, especially in terms of privacy and security. But altogether, we were advised not to think of solution-first, so we focused on creating a good solution first and integrating a partner technology second.

For all the interviews, our group prepared the questions in advance and had an appointed interview facilitator and others who were taking notes. At the end of each interview, the team concluded the main findings from the discussion and how that might affect what we have learned so far.

As we were approaching the CERN bootcamp event, we made some cuts to the scope of the problem, and our team has also identified the final problem area: Improving the traceability (collection & segregation) for e-waste, primarily for batteries and exploring options for solar panels.

While the team had many discussions on exact recycling technologies, materials, and battery chemistry, we knew that we are not experts of this topic, so instead, we decided to focus on narrowing the gap between how many devices are produced vs. recycled. And this recycling rate improvement also gave us a clear purpose on potential actions that can be taken, something that is expressed in more detail in the final solution part of the report.

After deciding on the challenge, we created our team poster and named ourselves E-Waste Warriors (Figure 5).

Figure 5: The team poster for E-Waste Warriors (team-created picture).

4.4 CERN Bootcamp in Geneva

With the whole project team's arrival to Geneva's CERN Bootcamp, the last stage of our group exercise began. After our SDG-12 team addressed the problem phase of the Double Diamond framework (Design Council s.a.) with earlier activities, now it was time to dive into the solution part.

The intense week started with some introductory sessions about both CERN and the IdeaSquare space, where we learned some insights about how things came to be, as well as got to know the advisors we will be working. It was fascinating to learn about some the innovations that were originating from CERN, and it was even clearer for our team how IdeaSquare could contribute to some of these future projects with its activities.

The bootcamp's week largely followed the design sprint method (Knapp et al. 2016) described earlier, focusing each day on different activities. Starting on

Monday with exploring the problem and ending on Friday with prototype validations/presentations.

On Monday, our team clarified the problem that we wanted to address and how much we wanted to look into the process of recycling, legislation, economics, health hazards, and other aspects. With brainwriting and dot-voting, we were able to effectively narrow down our focus area (Figure 6). We used the combination of these two tools quite often during our group work, as we found it effective to generate ideas alone and then discuss and vote on those items collectively. The process helped the team express opinions in an effective manner while being mindful of the available time.

Figure 6: The team discussing problems, ethics, and legislation during a bootcamp workshop (team-created photo).

On Tuesday, our group wanted to come up with initial solution ideas for the discussed challenge. The problem statement on improving traceability proved to be a useful compass for our discussions, ensuring that we do not go off-topic into recycling activities, materials, or other aspects of the problem that we do not want to cover for the exercise. To facilitate the solution process, each of us gathered ideas on what could be an effective way to address part of the challenge.

As a reminder, our problem statement was *improving the traceability (collection & segregation) for e-waste, primarily for batteries and exploring options for solar panels*.

From the early discussions on Tuesday, we realized that we might not find a single, simple solution for this challenge, but our proposal will have multiple angles and ideas. We identified four concepts that we want to include in the solution: technology, process, legislation, and reward. Without the combination of these components, no single idea can really succeed, and we wanted to provide a comprehensive end solution, not just an easy one.

On Wednesday, we continued to draft our final solution and merge individual proposals into a group suggestion. We used a combination of idea critique and personas to challenge each other's ideas – with this method, we impersonated various stakeholders needed for the solution to work (consumers, governments, manufacturers, and sellers) and tried to find the weak points in the proposed ideas. At this stage, we realized how the consumer might need motivation to do more e-waste recycling, or the interconnected relationship between governments and manufacturers. To ensure our solution remains cost-efficient and scalable, we took some inspiration from the Business Model Canvas to validate whether we can scale any suggestions to multiple countries and cities. As the day concluded, we assembled our final idea, capturing what will be demonstrated in the prototype and what other attributes will only be detailed in this final report. This is detailed in the next section of the report.

For Thursday, our group's main task was to plan and assemble the prototype and the final presentation. For the prototype, we quickly agreed to create a video that will feature some roleplay and process demonstration. Due to the complex nature of the solution, demonstrating various details required an effective medium. To map out who does what, we storyboarded our concept and broke it down into individual tasks for the day to finish everything on time (Figure 7).

Figure 7: Initial storyboard for the video prototype (team-created picture).

After a long day of work, we finalized our video prototype by Thursday evening. The final material contained a talking robot as a narrator (made in Adobe Character Animator), public images about the problem for context setting, as well as roleplay videos and other illustrations to explain the solution. The four-minute video ended with a brief summary, where we recapped our team's proposed ideas.

Finally, on Friday, it was time to practice our presentation in a "shark tank" session, where our instructor teachers and CERN staff provided useful feedback to our first presentation version. Taking the learnings, we promptly adjusted the presentation and the video, to be able to deliver our message more clearly.

Our SDG-12 team presented its final solution on Friday afternoon in front of a wider audience, after which the audience was able to ask questions and probe our thinking. Overall, our group was happy with how the presentation was delivered, and we felt we were able to explain not only the problem but also how our solution could address this very real and pressing need around e-waste and batteries.

At the conclusion of the CERN Bootcamp, everyone gathered around outside the IdeaSquare building to share insights and feedback on the intense week (as seen in Figure 8).

Figure 8: The wider project team shares positives, future wishes, and learning during the last session of the bootcamp (team-created photo).

5 Final Solution

According to data from the United Nations' fourth Global E-waste Monitor (GEM), the amount of electronic garbage produced worldwide is increasing five times faster than the amount of e-waste that is reportedly recycled. The 62 million tonnes of e-waste produced in 2022, according to ITU and UNITAR analysis, would fill 1.55 million 40-ton vehicles, or roughly enough trucks to create a bumper-to-bumper queue that would circle the equator (Baldé et al. 2024).

On the other hand, in 2022, less than twenty-five percent (22.3%) of the year's total mass of e-waste was recorded as having been properly collected and recycled. This indicates that $62 billion worth of recoverable natural resources remain unaccounted for globally, increasing the danger of pollution to communities worldwide. The production of e-waste is predicted to rise by 2.6 million tonnes annually worldwide and reach 82 million tonnes by 2030, a 33% increase from 2022. Any abandoned item that has a plug or battery is referred to as "e-waste," and it is dangerous for human health and the environment because it contains substances like mercury that can damage the brain and nervous system. (Baldé et al. 2024)

The analysis projects that the reported collection and recycling rate would fall from 22.3% in 2022 to 20% by 2030 due to the alarming global increase in e-waste output and the widening gap between recycling efforts. Some of the factors contributing to the gap's widening include technological advancements, rising consumption, fewer options for repairs, shorter product life cycles, society's increasing electronification, subpar design, and a shoddy infrastructure for treating e-waste. (Baldé et al. 2024)

The analysis emphasizes that the benefits—which include lowering hazards to human health—would outweigh the costs by more than US $38 billion if nations could raise their rates of e-waste collection and recycling to 60% by 2030. Additionally, it says that despite rare earth elements' special qualities being essential for developing future technologies like e-mobility and renewable energy generation, the globe "remains stunningly dependent" on a few nations. (Baldé et al. 2024)

5.1 million tonnes (8.2% of all e-waste sent worldwide) in 2022, of which 3.3 million tonnes (65%) came from unapproved, unrecorded transfers from high-income to middle- and low-income countries. Toys, microwaves, hoover cleaners, and e-cigarettes are just a few examples of small devices that account for about 33% (20.4 million tonnes) of all e-waste, of which 12% is recycled. With a documented collection and recycling rate of only 22% (2.4 million tonnes), small IT and communications equipment (such as laptops, cell phones, GPS units, and routers) accounts for 4.6 million tonnes of e-waste. Compared to the 600,000 tonnes in 2022, the expected quantity of retired solar panels in 2030 is four times higher. (Baldé et al. 2024)

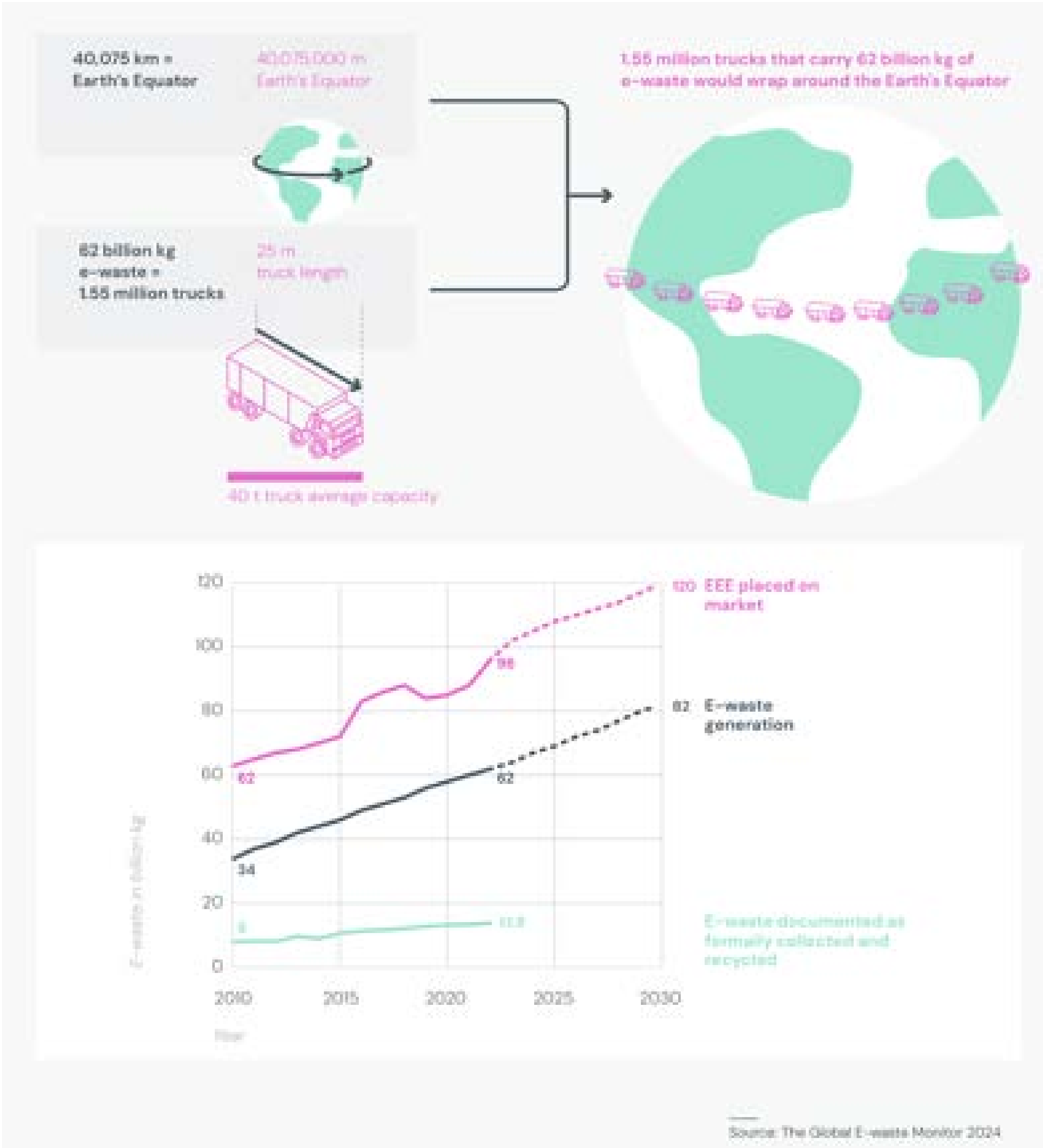

Figure 9: Headline Figures of E-waste from 2010 to 2030. (Baldé et al. 2024)

The group's primary goal is to close the disparity between the amount of e-waste produced and collected for recycling, creating a positive environmental impact. The team believes there is no easy, single solution for this problem, so during the many discussions and workshops, we realized that a comprehensive solution would need to include technology, legislation, process, and reward attributes. Below, we explain the various solution components one by one, revealing how those could form into a complete proposal.

Solution components

5.1 Increasing the number of e-waste collection points

Dedicated bins for collecting electronic waste are essential to help increase the recycling rate of the devices. If there is no container near customers, or those cannot be easily recognized, even if someone would want to do the right thing and recycle, they will have a hard time achieving their goals. The suggested containers should be thoughtfully positioned in accessible areas like malls, office complexes, and larger residential neighborhoods. These would offer a practical way for people to get rid of unneeded electronics. In addition, the containers could assist with keeping dangerous materials out of landfills, where they can cause negative effects on the environment.

The number and location of bins should be decided based on population statistics, the quantity of e-waste generated, and further research. During the initial testing of this new solution, a dedicated area or city could participate in the test, and with the help of proper instrumentation and measurement, the area could get measurable results by utilizing this solution alone.

5.2 Barcode-based tracking for electronic items

Using barcodes in electronic waste is the second suggested fix. As not all battery types have recycling facilities available in one location, having a barcode printed on the device’s packaging, on the device itself, and on the battery inside would help official parties get more information about the device and the battery.

Figure 10: A person holding a smartphone with an embedded tracking barcode on the back side that is used to track the lifecycle of the device (the team's computer-generated image with help from Microsoft Copilot)

By scanning the code visible in Figure 10, recyclers would know the device details, including the chemistry of the battery. This would make it easier to make informed decisions on recycling when it arrives at a recycling facility – for example, how and where to recycle the particular battery.

Additionally, this barcode could be connected to a central database operated by an independent organization, where the key lifecycle stages of the device could be tracked (Figure 11), like when it was manufactured or sold, similar to currently available package tracking solutions.

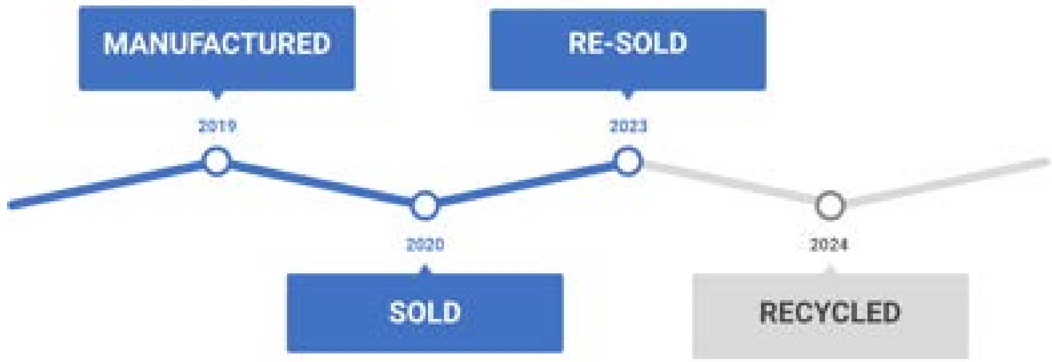

Figure 11: High-level illustration of what events could be tracked by the central database with the embedded device barcode (team-created picture)

The independent organization could operate inside the European Union and, with additional legislation support, work with manufacturers, sellers, resellers, and recyclers to implement support for the central system. With the use of this technology, gadgets that could end up in mixed rubbish or remain unused in homes can be readily traced and gathered for recycling. For this to occur, each product should have a specific expiration date. Additionally, the user should have the ability to upgrade the device's performance if they believe it can be utilized beyond the manufacturer's recommended expiration date. Based on the advancements made, this suggestion can have a lot more added to it.

For the underlying technology and database, the team looked into the capabilities of the Random Power solution from the listed ATTRACT technologies. While the team initially concluded that this provider's solution might be too costly or complicated for the first version to implement, Random Power might still be able to provide value in terms of security and privacy.

One aspect of the Random Power solution that could be useful is the ability to extract endless sequences of bits from quantum events, providing top-quality entropy at high throughput (Random Power s.a.). This output then could be used to generate encryption keys for the central database, or in the creation of unique barcode IDs when manufacturers request a new barcode for a new device. As privacy is important, this added layer of security can ensure that the database is only accessible to authorized parties, and reduce the risks of unauthorized access.

Regarding the scalability of this potential upgraded version, Random Power advised the team that the number of Random Power circuit boards (Figure 12) is dependent on the data volume. A single board would be able to generate 1 GB of "random bits" per second for encryption purposes. Based on the vendor's estimation, a single server with multiple boards would likely cost around 40 000 euros. With this implementation, a smaller region or country could be covered, which would make the initial solution rather expensive.

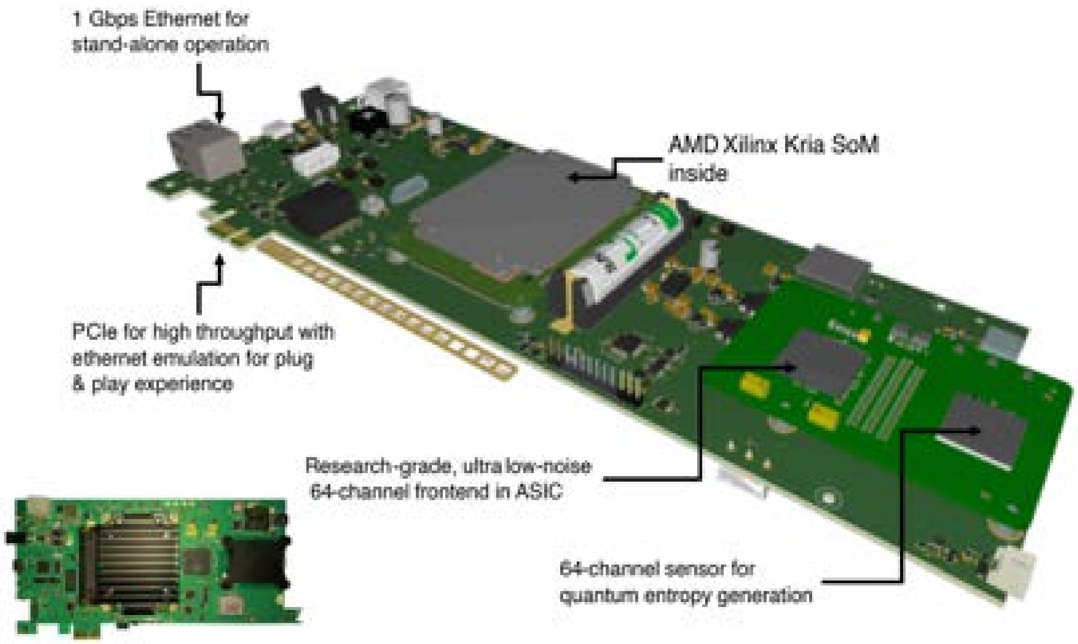

Figure 12: 64x Multi Generator Board from Random Power's Product Brief (Random Power s.a.)

Of course, with the development of the technology and further scalability, lower prices per board (thus, lower prices per operation) could be achieved.

In the next paragraphs, we further detail the potential commercial applications of the barcode-based technology, but without relying on Random Power's implementation for simplicity.

Potential Commercial Applications

An e-waste monitoring system that uses barcodes has a lot of commercial applications potential and can improve e-waste management accountability and efficiency (FasterCapital, 2024).

Enhanced Tracking & Traceability: Barcodes provide every waste item a special identification number that makes it possible to trace it precisely throughout its existence. Waste managers can track the transit, storage, and disposal of organic waste, hazardous trash, and recyclable materials with barcodes. Manufacturers and retailers can monitor a product's lifecycle with the aid of barcode labels (FasterCapital, 2024).

Sorting and Processing: At different points in the waste management process, barcodes make effective garbage sorting possible. Waste collection centers, recycling facilities, and disposal sites can readily detect and categorize objects that have unique barcodes attached to them. Recycling facilities can use barcode scanning to obtain device and battery details, enabling them to identify and sort incoming e-waste more effectively. This ensures that different types of e-waste are processed effectively, maximizing material recovery and streamlining the recycling process (FasterCapital, 2024).

Compliance and Reporting: Barcodes make it easier to follow rules. For example, environmental concerns can be reduced by properly tracking hazardous garbage. Also, barcodes automate data entry, which lowers human error. There will be no more manual waste weight or type recording (FasterCapital, 2024).

5.3 Education

Education is essential to the management of e-waste because it raises awareness, modifies behavior, and gives people the information and abilities they need to manage e-waste properly. The following are some ways that education could support more efficient e-waste recycling in the future.

Awareness and understanding: Educational programs increase public knowledge of the risks to the environment and human health posed by inappropriate disposal of e-waste. People who are aware of the dangers associated with the harmful materials found in e-waste are more inclined to recycle and dispose of their waste properly.

Behavioral change: Education promotes ethical consumption and disposal practices, leading to a change in behavior. Encouraging people to recycle, reuse, and dispose of electronic gadgets correctly will help cut down on e-waste and encourage environmentally friendly behavior.

Policy and advocacy: Educating decision-makers in government and business on the problems and solutions related to e-waste can help create more efficient laws and industry standards. Consequently, this helps to build strong infrastructure and e-waste management systems.

Community engagement: Educational initiatives within local communities can spur group efforts to manage e-waste. Public awareness campaigns, school programs, and community seminars can include local residents in e-waste collection and recycling efforts.

Innovation and research: Academic establishments are essential for the advancement of e-waste management technology and methodology research. Education stimulates innovation, which results in the creation of novel methods for recycling materials, procedures for recovering them, and designs for sustainable products.

Through the incorporation of e-waste education into educational institutions like schools and universities, the workplace, and local communities, we may cultivate a more knowledgeable and proactive populace that tackles the problems associated with electronic waste, thereby promoting environmental sustainability and public health.

5.4 Legislation

According to the 2024 Global Environmental Monitor:
There has been a documented improvement in the management of illicit e-waste exports in West Africa due to enhanced enforcement and regional cooperation. But in January 2023, a group of organized criminals was discovered smuggling more than 5 million kg (331 containers) of electronic garbage into Ghana, Senegal, Mauritania, and the Canary Islands. Furthermore, in 2020, a network that was exporting 2.5 billion kg of materials, including 750,000 kg of e-waste with fraudulent certification, to multiple African nations was apprehended by Spanish police. Although e-waste imports into Africa are being tracked, they are infamously hard to regulate." "Major ports of entry for used EEE have been identified as Durban (South Africa), Bizerte (Tunisia), and Lagos (Nigeria), three of Africa's busiest ports. This suggests that e-waste shipments continue to evade the Basel and Bamako Conventions." Using the StEP Initiative person-in-the-port methodology, an Irish research discovered that roll-on/roll-off vehicles were the primary means of transporting old EEE from Ireland to West Africa, as opposed to containers. According to the study, which conducted vehicle and enforcement document inspections at Ireland's Ringaskiddy port, 17,319 kg of used EEE were exported from Ireland annually, and about one in five exported automobiles contained used EEE. The study scaled sample data to annual shipment estimates. (Baldé et al. 2024)

This is the perfect time to review the current legislation to see if it should be changed to forbid the unlawful movement of electronic waste. According to experts, there are already many loopholes in the legislation that are being exploited by different organizations to smuggle e-waste into developing and underdeveloped countries. Therefore, the group suggests that laws be made increasingly stringent, that waste not be carried across international boundaries and that governments assume moral responsibility for ensuring that waste generated in a given nation is treated there.

Every product that is recyclable should be required to be recycled by law, according to the government. Consequently, more and more products will be recycled, which will in turn encourage more and more people to enter the recycling market as a potential source of income.

In addition to this, legislative support and new laws for requiring the above-mentioned barcode system would help manufacturers, (re)sellers, and recyclers to treat this as a requirement rather than a recommendation. If there is a mandatory system in place that helps recycling, then it would be reasonable to expect improvements in the effective recycling rate of electronic devices.

6 Conclusion and Reflection

6.1 Conclusion

Effective e-waste management is crucial to mitigating environmental and health hazards. Implementing strategies such as increasing e-waste collection points, utilizing barcode-based tracking systems, enhancing education on e-waste management, and strengthening legislation can significantly improve e-waste handling and recycling.

During the intense workweek at CERN, the E-Waste Warriors team has drafted the recommendations explained below.

1) Increasing e-waste collection points

Implementation: Expand e-waste collection bins in high-traffic areas like shopping malls, workplaces, and residential neighborhoods, aligned with population density and e-waste generation.

Outcome: Facilitates proper disposal, reduces hazardous materials in landfills, and improves recycling efficiency by enabling the general society to be more aware of these collection points as well as make them more reachable.

2) Barcode-based tracking system

Implementation: Mandate barcodes on packaging, electronic devices, and their batteries. The barcode-based system would be connected to a central database, where authorized parties would be able to see additional device and battery information, as well as able to log entries in the lifecycle journey of the item.

Outcome: Enhances traceability, enables informed recycling decisions, and reduces improper disposal or unused e-waste.

3) Education

Implementation: Launch educational campaigns targeting consumers, businesses, and policymakers on proper e-waste disposal, recycling benefits, and environmental impacts. Especially focusing on educating youth in schools from an early age.

Outcome: Increases awareness and responsible behaviors, promoting sustainable consumption and disposal practices.

4) Legislation

Implementation: Review and strengthen e-waste legislation to close loopholes allowing illegal exports. Enforce regulations ensuring domestic e-waste processing and mandate recycling of all recyclable products. Support the barcode-based system with applicable laws to make it enforceable for manufacturers, (re)sellers, and recyclers.

Outcome: Curbs illegal e-waste movement, ensures ethical waste management, and boosts the recycling industry through a regulatory environment encouraging compliance and innovation.

By adopting these recommendations, governments, businesses, and communities can work together to manage e-waste more effectively, reducing its environmental impact and promoting sustainability.

6.2 Reflection

Overall, the CERN Bootcamp project, including the preparations, the group work, and the intense week itself, was interesting and engaging. From getting to know the team early on, establishing working practices, getting to know the SDG-12 problem area, and coming up with the solution was a rewarding journey. During the work, the team not only got much closer to the global e-waste problem, but during interviews and desk research, the group also got a first-hand experience with the scale of the challenge and had the opportunity to think of possible solutions.

While teamwork is never easy due to availability, different opinions, and ways of working, the group was able to find a way to collaborate effectively online and in person, balancing the workload across the members. The in-person bootcamp and its conclusion provided a great learning experience for everyone involved, and with the course, our team was able to develop its communication, project management, and teamwork skills in a friendly but professional setup.

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