

# How AI can advance the Circular Economy with Medical Device Recycling

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## Abstract

The rapid growth of the healthcare industry has brought remarkable advancements in medical devices, enhancing patient care and improving treatment outcomes. However, the increasing disposal of medical devices poses significant environmental and economic challenges. This white paper aims to shed light on the urgent need to recycle medical devices, exploring the environmental impacts, regulatory considerations, and benefits of implementing a robust recycling program. By recognizing AI's value in recycling medical devices and reverse supply chain, we can work towards a more sustainable healthcare system that minimizes waste generation and maximizes resource utilization.

## Introduction

In recent years, sustainability has emerged as a pressing global concern. The evidence of climate change is becoming increasingly apparent with extreme weather events, rising temperatures, and melting ice caps, highlighting the urgency of addressing environmental issues (United Nations, 2023.) However, despite the overwhelming scientific consensus on climate change, there are differing opinions and hesitations regarding the need to adapt. The detrimental impact of human activities extends beyond climate change.

This unsustainable trajectory significantly threatens our planet's delicate balance and future generations' well-being. We must acknowledge the reality of these challenges and embrace the necessary transformations to ensure a sustainable future.

Proper use and reuse of materials is a cornerstone of Circular Economy that promotes a sustainable future by relying less on virgin materials. Urban mining and waste management embrace environmental protection and avoid the loss of irreplaceable materials, leading to a greener future.

## Health Care and Recycling

When we think about the healthcare industry, it is easy to forget about its impact on the environment. The healthcare industry requires substantial use of equipment, including medical devices that are often made of plastic and contain materials that can go through reprocessing and recycling. Unfortunately, they are usually in use once, representing missed value. Still, when properly recycled, they can bring value back to the producer and user while reducing carbon footprint and the burden on our already suffering landfills.

Manufacturers create medical devices for single-use, then throw them away, disregarding the long-term possibilities. The reason is the potentially hazardous material they sustain after use, as it can become a danger to anyone who reuses the device. Interestingly, according to the World Health Organization, the amount of non-hazardous waste is surprising:

"Of the total amount of waste generated by healthcare activities, about 85% is general, non-hazardous, comparable to domestic waste. The remaining 15% is a hazardous material that may be infectious, chemical, or radioactive." (World Health Organization [WHO], 2018).

Suppose most of the waste generated by healthcare spaces consists of non-hazardous materials. In that case, the step to divert material from landfills, reduce toxic emissions, and bring valuable materials back into circulation through recycling is possible.

The real question is how we can approach this challenge and how it can benefit our planet's sustainability.

### **How Does the Medical Field Impact Sustainability?**

While healthcare may not be the first industry that comes to mind when thinking about the negative impact on the sustainability of our planet, research says otherwise.

Jennifer Dunn, Associate Professor of Chemical and Biological Engineering and Director of the Centre for Engineering Sustainability and Resilience at Northwestern University, quotes Delgado saying, "8.5% of U.S. greenhouse gas emissions come from the healthcare sector." (Delgado et al., 2021).

While the positive impact of medical devices is significant due to their necessary effect on the user, it also negatively impacts our planet. Even though someone's life is the primary concern, there must be other ways to address the environmental harm.

The healthcare system directly impacts sustainability in various ways, including sourcing raw materials, manufacturing and transporting medical devices, decontamination, repairing and sterilizing medical instruments, and disposing of medical devices and packaging, particularly from the incineration of single-use plastics.

According to the National Health Service (NHS), over 1.4% of all emissions generated are due to single-use devices (Gören et al., 2021), some of which can be reprocessed and reused to save emissions and money.

The impact of medical devices on sustainability is worrying. An increase in health issues in the future will bring an increase in the creation of single-use medical devices that continue to impact our planet negatively.

Current medical devices get created with single-use in mind, even if reuse is possible. Manufacturers and healthcare facilities rarely consider it. An example of this was when researchers from Northwestern University found that Laryngoscope batteries provide around 2,400 minutes of power; however, the batteries are discarded after only a minute of use (Northwestern University, 2022.) Unfortunately, batteries corrode; their chemicals soak into the soil, contaminating groundwater and surface water.

Not only do medical devices cause substantial pollution, but according to Practice Greenhealth, the leading sustainable healthcare organization, 29 pounds of medical waste is created daily per bed, totalling 5.9 million tons annually in North America (Practice Greenhealth, 2020). The question is "What is being done for medical devices to be reusable?"

## **Reprocessing Medical Devices**

The reason behind the lack of medical device recycling is quite simple. Companies believe in the importance of single-use devices due to biohazardous contamination and spending less on non-recyclable materials. However, some of these devices can be reused once correctly reprocessed.

Reprocessing medical devices has become familiar as the world aims for a Circular Economy and must keep gas emissions low. To ensure patient safety and prevent the risk of infection from contaminated devices, specific medical devices labelled as reusable undergo a thorough reprocessing process. The comprehensive, multistep procedure involves meticulous cleaning and disinfection or sterilization. When the reprocessing instructions provided by the manufacturer are diligently followed, the device can be safely used again for the same patient or others. Proper reprocessing of reusable medical devices is crucial for maintaining patient safety and preventing potential complications.

Many companies reprocess medical devices for reuse; however, it is difficult and time-consuming. Let's explore how medical device recycling can be improved by implementing new and emerging technologies such as AI and robotics for creating efficiency and accuracy.

### **AI and Reprocessing Medical Devices**

AI offers valuable support to companies specializing in medical device reprocessing. Through advanced data analysis and machine learning algorithms, AI can analyze reprocessing data, identify patterns, and optimize protocols for improved efficiency. AI algorithms can predict equipment maintenance needs, ensuring uninterrupted operations. Additionally, AI-powered image recognition and computer vision assist in quality control and detecting defects or contamination. AI aids regulatory compliance by interpreting guidelines and automating checks. Workflow optimization and knowledge management systems enhance productivity and provide instant access to information. Overall, AI can empower companies in medical device reprocessing by enhancing processes, ensuring compliance, and improving patient safety.

### **What About the Recycling of Medical Devices?**

Not all equipment can go through reprocessing. Items that cannot add to our landfills increase the carbon footprint we aim to reduce. The materials going to the landfills are usually difficult to recycle, as the valuable materials are challenging to identify or extract from the current device. They are also potentially toxic; having manual labour becomes nearly impossible as it is dangerous for people to work with equipment that may be toxic for humans.

The current disposal methods for medical devices, including incineration and landfill, present significant environmental and human health risks. These methods contribute to air pollution by releasing toxic gases and hazardous emissions. Landfills contaminate soil and groundwater, harming ecosystems and water sources. Workers involved in waste management may face health hazards due to exposure to harmful substances. Moreover, improper disposal can spread infections and the loss of valuable resources (Lorke, 2021). Manufacturers must prioritize the reusability of medical devices, as this can help conserve natural resources and minimize the environmental impact of waste. Safe and sustainable medical waste management practices, including recycling and adherence to regulations and guidelines, must be emphasized to mitigate these risks effectively.

Medical devices are subject to stringent regulations to ensure patient safety, efficacy, and quality control. The U.S. Food and Drug Administration (FDA) provides guidelines to ensure medical device safety, effectiveness, and quality. The guidelines outline regulatory requirements for manufacturers in bringing new devices to market, establishing, and maintaining quality systems, monitoring device performance, reporting adverse events, implementing UDI labelling, addressing software-based devices, and protecting against cybersecurity threats. Manufacturers and stakeholders should refer to the FDA's official website for comprehensive and up-to-date guidelines for their medical devices. Compliance with regulatory guidelines, such as those set forth by the FDA, is essential during recycling. Furthermore, the intricate designs, electronic components, and software of medical devices make their disassembly and recycling complex tasks, requiring specialized knowledge and equipment. Contamination control and infection prevention protocols are also crucial to safeguard healthcare workers, recycling staff, and the environment.

### **Medical Device Recycling Presents Several Challenges**

Some challenges are as follows:

- Device complexity makes it difficult to disassemble and recycle these intricate devices without causing damage or releasing hazardous materials.
- Proper decontamination and infection control protocols must be followed to eliminate potential risks associated with recycled devices.
- Medical devices consist of various materials that require efficient separation and processing methods to extract valuable resources and appropriately handle hazardous substances. Data security and patient privacy are essential during recycling to sanitize and protect sensitive information.
- Many Medical devices are made of plastics (Straits Research, 2021) and different polymers such as PVC. In order to recycle these plastics properly, they need to be separated based on their polymers.
- The limited availability of recycling infrastructure and specialized facilities can hinder the recycling process, resulting in higher costs and longer processing times.
- Maintaining traceability and documentation of medical devices is crucial for regulatory compliance and accountability, necessitating efficient tracking systems throughout the recycling process.

### **What Can AI Bring to the Table with Medical Device Recycling?**

AI vision technology offers promising solutions to address challenges in medical device recycling. By leveraging computer vision algorithms, AI can assist in disassembling complex devices by analyzing images or videos and guiding recycling experts to prevent damage and hazardous material release. AI vision can also help identify and assess mixed materials enabling effective separation measures.

AI algorithms can categorize, and sort materials based on visual characteristics, facilitating efficient material recovery and specialized recycling. AI vision aids data security and patient privacy by automatically detecting and sanitizing sensitive patient information during recycling. Moreover, AI

enables automated device information capture and tracking for accurate documentation and traceability. By combining AI vision with human expertise, medical device recycling can benefit from enhanced efficiency, accuracy, and safety.

As an example, a case study has been done by Neatco Engineering for proving the ability to utilize AI vision to extract meaningful information from medical devices such as REF and LOT numbers, and barcodes in a mass loading onto a conveyor belt. AI can recognize a device through AI vision by recognizing the shape of the item. These numbers serve as unique identifiers that enable accurate identification, tracking, traceability, and reusability of individual devices throughout their lifecycle. By associating REF and LOT numbers with specific batches or lots of devices, companies can effectively monitor product quality, comply with regulatory standards, and facilitate post-market surveillance. These numbers play a critical role in quality control, regulatory compliance, post-market safety monitoring, and providing efficient customer support. Ultimately, having access to REF and LOT numbers allows medical device companies to ensure product integrity, meet regulatory requirements, and deliver high-quality devices to healthcare providers and patients.

However, there are many unexplored possibilities for AI applications to improve Medical Device recycling. Neatco Engineering is seeking opportunities to explore new ways to leverage its industrial R&D experience with AI machine vision and robotics to explore those applications, whether it is automated disassembly, sorting, or data collection and analysis of used or outdated medical devices.

#### **AI for the Circular Economy by Neatco Engineering**

In 2021, Neatco began product development, creating an AI device with the capabilities through neural networks to recognize material coming through to create a safe and efficient recycler process. However, it was just the beginning. The AI device, 'IntelSight,' has capabilities beyond comprehension for the average individual.

In recent years, Neatco has conducted extensive research on implementing AI in various recycling industries, including medical device recycling. AI in recycling processes offers significant benefits, such as efficient data processing, improved compliance with regulations, and accurate waste stream characterizations. Despite these advantages, the widespread adoption of AI in the recycling industry faces several barriers. Limited awareness of AI applications, the high costs associated with robotic sortation, and the need for readily available tools for creating AI solutions hinder its mainstream use.

One notable finding from Neatco's research is that AI excels in handling material variation, a common challenge in recycling. Unlike traditional machine learning or mechanical equipment, AI can recognize temporal patterns and variations, making it a valuable automation tool. It can process materials of different shapes, sizes, and orientations, allowing for accurate identification and sorting, even when the data input is inconsistent.

Through the work of case studies, utilizing AI to automate the recycling process for printer toner, despite variations in toner cleanliness, AI was trained to recognize different brands and types of printer toners, having precise identification for billing and auditing purposes. The AI system detects objects, creates bounding boxes around them, and labels them according to the OEM and toner type, showcasing the effectiveness of AI in recycling applications.



Neatco's research indicates that AI can address challenges related to standardized codes and varying packaging formats for medical device recycling. AI can detect and read barcodes or QR codes on medical device packaging, even when they are present in different orientations or conditions. By processing this information, AI can provide optimal data formats for further decoding and analysis using machine learning techniques. The process reduces complexity and costs, improving the efficiency of the system.

AI can assist in various stages of the recycling process, including material collection, robotic sorting, disassembly, and material recovery. AI can provide valuable information to recyclers during the collection process, enabling them to identify valuable materials based on characteristics such as type, brand, size, and value. In disassembly processes, AI can assist operators by projecting markers and guiding them through the disassembly steps, mitigating the turnover of experts. Additionally, AI can optimize equipment parameters in material recovery by utilizing visual or audible cues, ensuring high-quality output commodities.

Integrating AI into recycling processes holds great potential to enhance efficiency, reduce manual labour, and improve the overall recycling industry. By harnessing AI's capabilities, recyclers can overcome challenges related to material variation, automate complex tasks, and optimize equipment performance. Neatco's research underscores the significance of AI as an enabler of automation in recycling industries, offering solutions to long-standing challenges, and paving the way for a more sustainable future.

## **Conclusion**

In conclusion, the rapid growth of the healthcare industry has led to remarkable advancements in medical devices, improving patient care and treatment outcomes. However, the increasing disposal of medical devices presents significant environmental and economic challenges. This white paper has highlighted the urgent need to recycle medical devices and has explored the environmental impacts, regulatory considerations, and benefits of implementing robust recycling programs.

Recognizing the value of AI in recycling medical devices is essential to achieving a more sustainable healthcare system. The healthcare industry significantly impacts sustainability, including greenhouse gas emissions, waste generation, and resource utilization. We can reduce waste, minimize environmental pollution, and conserve valuable resources by focusing on recycling and reusing medical devices.

Reprocessing medical devices for reuse is already practiced but requires time and effort. AI can play a crucial role in improving the efficiency and accuracy of the reprocessing process, making it more viable and cost-effective. Recycling companies can optimize protocols, enhance quality control, automated checks, and improve productivity through advanced data analysis, machine learning algorithms, and AI-powered vision technology.

Not all medical devices can go through reprocessing. Those that cannot contribute to landfill waste and environmental harm. AI vision technology offers promising solutions for recycling these complex devices. By leveraging computer vision algorithms, AI can assist in disassembling devices, identifying contamination, categorizing materials, robotic sorting, and ensuring data security. Combining AI and human expertise can enhance efficiency, accuracy, and safety in medical device recycling.

The work conducted by Neatco has demonstrated the potential of AI in addressing challenges and improving recycling processes. Their research has shown that AI excels in handling material variation, can read and decode packaging information, and assist in various stages of the recycling process.

Integrating AI into recycling processes holds great promise for enhancing efficiency, reducing manual labour, and improving the overall recycling industry. By embracing AI's capabilities, we can overcome barriers, optimize recycling operations, and pave the way for a more sustainable future.

Recognizing the value of AI in recycling medical devices, we can work towards a more sustainable healthcare system that minimizes waste generation, maximizes resource utilization, and contributes to the well-being of our planet and future generations.

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## About Neatco's AI-vision Controller, IntelSight:



### Applications in Waste Management:

- Medical device recycling
- IT assets data collection, analytics, tracking, and reporting
- IT assets inspection, value estimation, and OEM detection
- Identifying devices with embedded battery
- PCB grading based on the number of precious metals
- Detecting valuable and sellable chipsets and components on PCBs
- Connectivity to websites and databases for tracking IT assets and value estimation for buyers
- Providing an online tool for the customer to evaluate their electronic devices and boards
- Battery classifications and sorting based on their chemicals
- Hazards detection prior to shredding
- Detecting metal concentration in shredded materials
- Identifying contamination in Zorba aluminum and ferrous lines
- Classifying plastics based on their polymers using IR cameras

### Process Monitoring and Control:

- Control different types of robots for sorting (IntelSort)
- Robotic dismantling of IT assets
- Control projectors for color coding on moving objects (Neatco's proprietary AI-Assisted Sorting technology)
- Control diverters and air-jets of sorting equipment
- Output monitoring of existing commodity recovery equipment and parameter tuning for improving their performance

**Main Features:** Rugged industrial design, scalable and compatible with common machine vision standards, variety of industrial I/Os, user-friendly, easy to install, train, maintain, and operate (no need for special AI skills), and affordable.

Neatco is your reliable and trustable AI technology provider with over a decade of working experience in WEEE recycling. To learn more about Neatco's **IntelSight**, a proprietary **AI-Assisted Sorting** solution, and receive a live demo, please contact us at [info@neatcoeng.com](mailto:info@neatcoeng.com) or visit us at <https://neatcoeng.com>