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Making the Case

A Circular Approach to Healthcare Equipment Life Cycle Management

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Symptoms to an Environmental Health Crisis

Our patterns predict our future, and as healthcare expenditures continue to rise and consumption of new technology accelerates, we as a society have created a habit of generating existential unnecessary electronic waste, better known as e-waste. Where might these discarded materials and components be revealed in our environment? An excess of 50 million tons of e-waste is produced globally each year **[1]** and can be found in either electronic graveyards in Ghana **[2]**, in the hands of over 50,000 salvage workers in India **[3]** or in the local landfills that feed into the soil and water sources that we farm on, contributing to regional toxicity-linked diseases and illnesses. Innovation is essential to deliver the highest quality of care that technology can provide. However, these advancements can also result in surplus manufacturing, excessive extraction of raw materials from mineral rich regions and accelerated depreciation rates of outdated technology. A system must be developed to balance production with resource utilization to address these concerning healthcare sustainability trends. This paper explores how circular economy principles can be applied to medical equipment to extend its life cycle, reduce capital expenditures and support resource-limited areas without compromising safety or quality of care. It also offers guidance to help healthcare organizations better understand the full life cycle of their technology and make more informed, sustainable decisions as they plan for their future equipment needs.

KEY TAKEAWAY

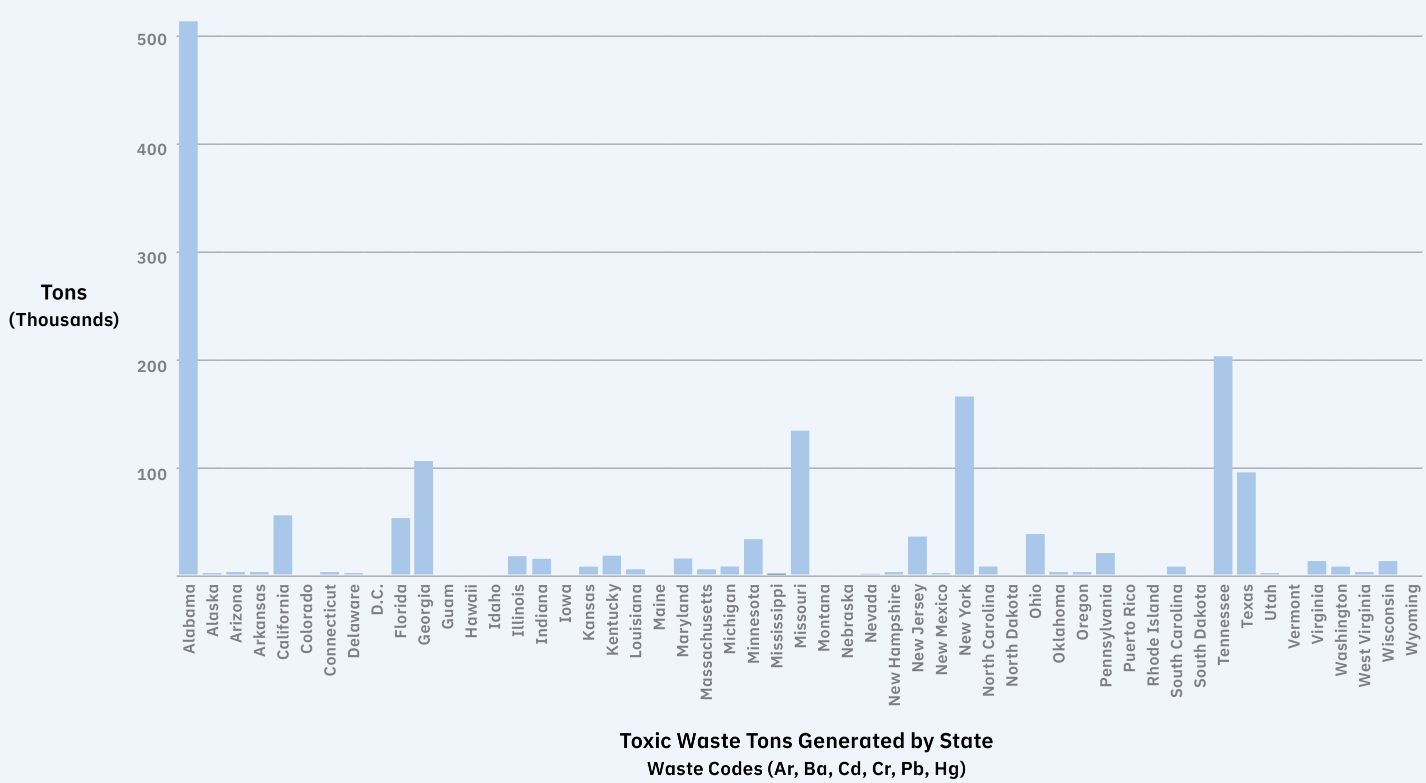
This paper serves to inform healthcare organizations of the public health risks from generating hazardous metal waste and recognize the economic potential in optimizing asset utilization. Delineating the stages of the life cycle of medical equipment is fundamental to identifying the decisions necessary at each phase for a proactive approach to life cycle management and longevity.

Pollution Exposure and Society's Health

Environmental pollution is a global issue that plagues our society. Despite the adverse effects metal exposure can have on public health, metal toxicity linked diseases are not easily recognized by healthcare professionals. In 2011, Ravinder Mmtani's article, "Metals and Disease: A Global Primary Health Care Perspective", examined the relationship of environmental and occupational toxin exposure to illnesses globally. Symptoms due to heavy metal exposure include neurological damage, cardiovascular effects, diarrhea, and kidney damage to name a few **[4]**. For the populations that are more susceptible to environmental toxins — such as children and pregnant women — the illnesses are even more severe. China currently ranks as the country with the highest levels of e-waste produced globally. The country that ranked the second in e-waste production and pollution was the U.S., despite being ¼ of the population size **[5]**.

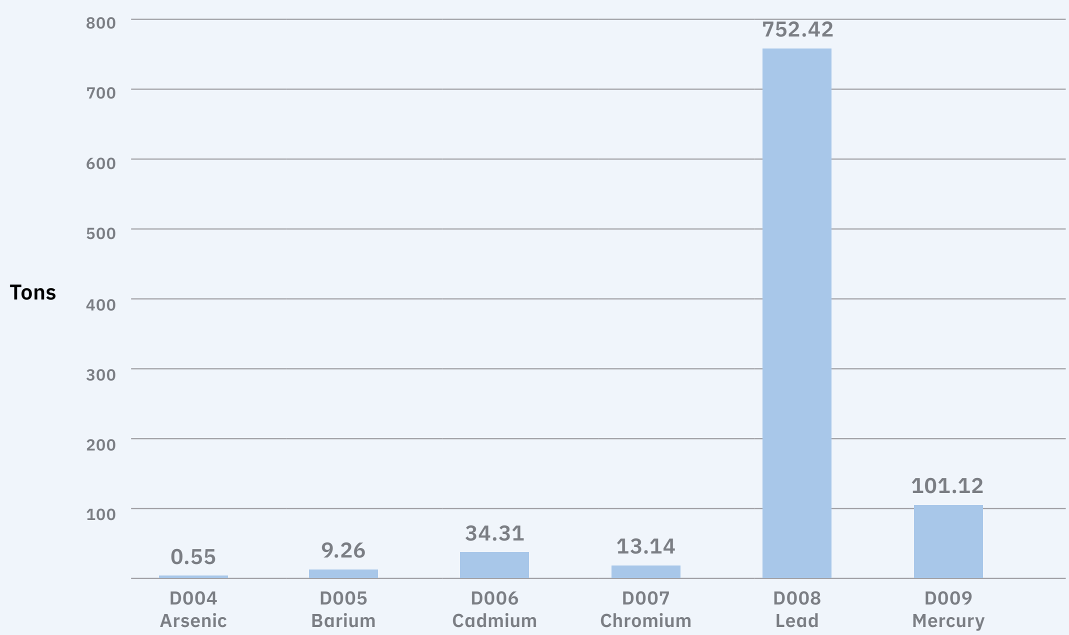
One beneficial initiative from the U.S. that encouraged climate conscious thinking was the Health Sector Climate Pledge in 2022 by the Department of Human Health Services. Hospital organizations and corporations committed to reducing greenhouse gas emissions by 2030, beginning with identifying which activities contribute to air pollution. Although research supports the importance biodiversity has on environmental health, it was not listed as a solution in the climate pledge. Assessing the land we develop our healthcare facilities on, while cultivating biodiversity, will help restore the balance we seek in climate change. Regarding land pollutants, the EU established the RoHS (Restriction of Hazardous Substances) in conjunction with the WEEE (Waste Electrical and Electronic Equipment) directives in 2003 to restrict the use of certain hazardous substances in equipment, including heavy metals typically used in e-waste production, and improve the retrieval of raw materials through reuse, recycling and other forms of recovery.

FIGURE 1: **United States EPA Resource Conservation and Recovery Act Biennial Report 2023**



With this concept in mind, we investigated further the data available from the EPA and charted the amount of toxic waste generated in the U.S. for the following hazardous metals - Arsenic, Barium, Cadmium, Chromium, Lead, and Mercury. **Figure 1** shows each state and how many tons of waste were produced in the hazardous heavy metal waste category. Factors not related to e-waste that contribute to the net total of hazardous metal waste per state may include parameters like location of manufacturing plants, chemical processing facilities, and state population. Although we could not quantify the waste that could be attributed to medical devices and equipment, we were able to chart the amounts of hazardous metal waste generated by the category identified by the North American Industry Classification (NAIC) as Health Care and Social Assistance. **Figure 2** shows the chart of how many tons of hazardous metals were generated by healthcare and social assistance in the United States. Lead was the most contributed hazardous metal waste generated by this industry. However, the cumulative quantity of the other metals is a significant amount of pollution and the impact to public health should not be underestimated.

FIGURE 2: **United States EPA Resource Conservation and Recovery Act Biennual Report 2023**



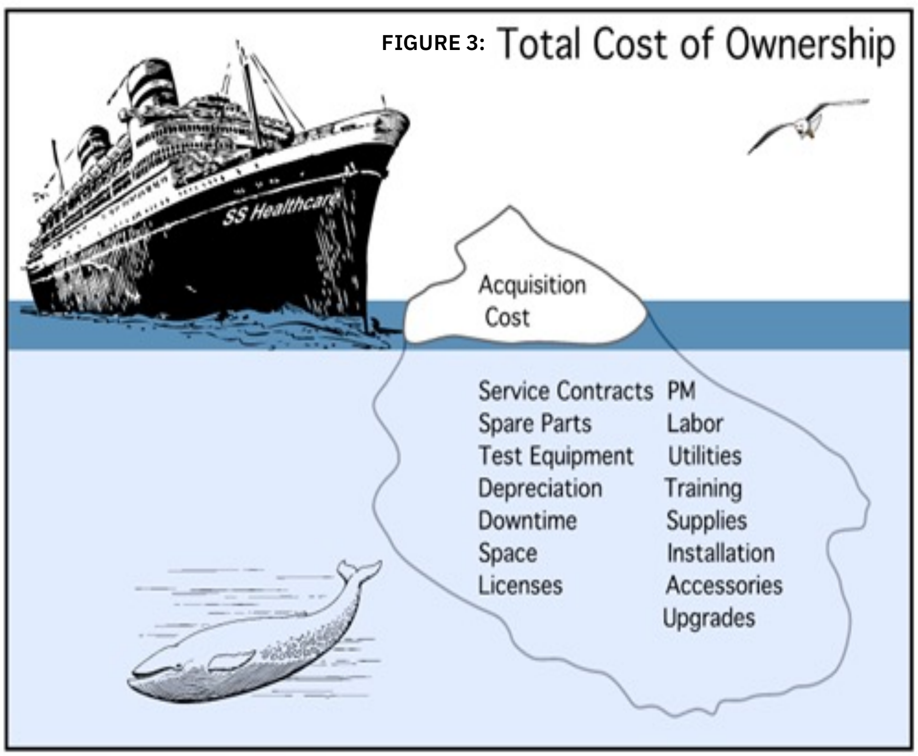
NAIC 52 — Health Care & Social Assistance
Waste Codes (Ar, Ba, Cd, Cr, Pb, Hg)

Healthcare Equipment Cost of Ownership

Healthcare equipment accounts for 15% to 20% of a budget for a new construction project **[7]**. Although this is a considerable portion of a project's cost, the equipment's total cost of ownership (TCO) during operation can have a greater influence on a facility's finances than its initial investment. **Figure 3 [8]** illustrates the perceived cost of acquiring an asset, versus the actual costs to maintain during its life span. The parameters facilities use to track TCO are not standardized by the industry. However, a combined effort between supply chain, Bio-med team, the chief financial officer, and input from infection control can help give a well-rounded picture of TCO and prepare a system to make informed and strategic decisions. Qualitative data like user satisfaction or technical support are important as well when evaluating the product's value. Methods that define and track equipment TCO parameters at the system and facility levels will be more telling of the value of the investment and help make informed future decisions, especially when evaluating the acquisition of a new product. This approach is a necessary step in mitigating extraneous expenditure and reducing technology consumption.

Facilities that have surplus equipment or underused assets are losing value in storage space and vital real-estate. There is opportunity to extend the use in rural areas that are in need of supplies and medical resources. The receiver's capacity to support the acquisition like staffing resources and infrastructure must also be considered before re-selling or donating. Since there are many decisions to be made during the lifespan of equipment, end-of-life planning must be evaluated at the beginning of product design.

FIGURE 3: Total Cost of Ownership

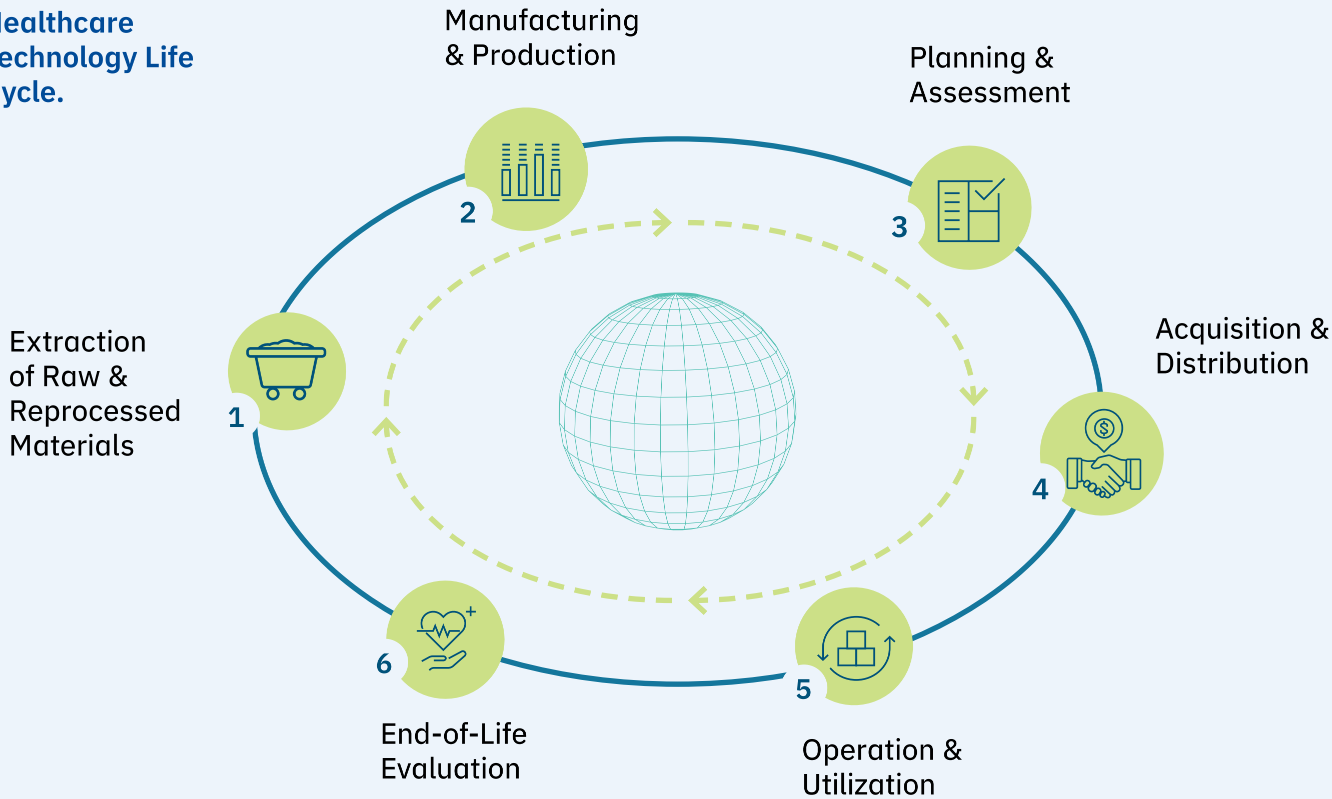


Credit: Ismael Cordero, Clinical Engineer; [9]

Healthcare Technology Life Cycle

Lean management is a great starting point to develop a plan to work towards zero net waste. **Figure 4** is our approach on re-defining the process and illustrating the life cycle stages of medical equipment to help identify the key decisions made at each phase. The diagram of a building life cycle is established in the International Organization of Standardization (ISO) under standard 21930. We referenced the ISO diagram as a foundation for our healthcare technology life cycle. Our re-defined cycle seen in **Figure 4** differs in that the initial stage entails design and composition evaluation, and the final stage of recovery is not an optional part to consider, but a necessary step in order to achieve circularity. Many of the life cycle definitions currently in the healthcare industry are linear and truncate at the original equipment manufacturer (OEM) end of service, omitting the process of disposal and depollution. These definitions are not a full representation of the entire process and exclude the most important element in the cycle, the environment.

FIGURE 4:
Healthcare Technology Life Cycle.



Extraction of Raw & Reprocessed Materials.

Evaluating medical equipment manufacturing includes assessing sustainable materials, reprocessed or refurbished components, and ethical sourcing aligned with owner values.

Manufacturing & Production.

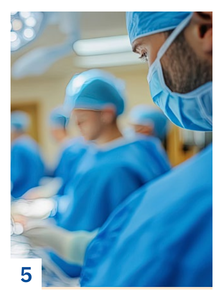
Reliable OEMs prioritize Product Life Extension (PLE) and modular design, ensuring easy part replacement, affordable maintenance, and user-friendly operation.

Planning & Assessment.

Regular inventory of existing equipment helps assess needs and surplus, ensuring effective budgeting and capital planning for healthcare renovations and new construction.

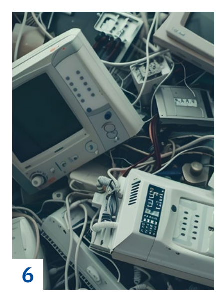
Acquisition & Distribution.

Refurbishing, leasing and Product as a Service (PaaS), offer cost-effective, sustainable alternatives to new equipment while reducing resource consumption.



Operation & Utilization.

TCO parameters like depreciation, performance, maintenance costs, manufacturer support, space value, and utilization are tracked to aid in making informed future investment decisions.



End-of-Life Evaluation.

Evaluating an asset's retirement phase guides disposal options, from trade-ins and refurbishing to resale, donation, recycling or landfill, with data security considerations.

1.EXTRACTION OF RAW & REPROCESSED MATERIALS

Methods to evaluate how the equipment is designed and manufactured include considering its degree of sustainable and non-toxic material, reuse of re-processed materials and metals, and/or refurbished parts from previously manufactured products. Many of the major biomedical manufacturers reside in Europe and are mandated to comply with RoHS (Restriction of Hazardous Substances). For companies that do not explicitly state RoHS compliance, investigating the the degree of hazardous material composition is necessary. Determining where the material is sourced will also help build awareness of how purchasing a product impacts the country of origin's economy and environmental resources.

2. MANUFACTURING & PRODUCTION

OEMs that design with integrity prioritize durability, modularity to allow for part replacement, affordability of maintenance, availability of parts, and also human factors when operating. Selections considering these factors can increase product life extension (PLE) and reduce excessive discarding of equipment.

3. PLANNING & ASSESSMENT

Taking inventory of existing equipment creates a foundation to assess the needs with the surplus. Procedures and programs adapt over time, particularly in healthcare diagnostics and treatments. Therefore, re-visiting how the equipment is implemented periodically and analyzing the operating costs will better prepare a project's budget and capital planning for facility renovation and new construction. Thoroughly investigating new technology before implementing may also improve outcome of utilization.

4. ACQUISITION & DISTRIBUTION

While there are many benefits to acquiring a new piece of equipment, some alternatives to purchasing new include selecting a refurbished item, leasing the equipment depending on the usage and cost evaluation, and Product as a Service (PAAS), which incentivizes manufacturers to prioritize PLE. Many vendors prioritize service as much as products they sell, and provide full-time support on campus in their contracts to help with utilization and customer satisfaction. These alternatives may help manage costs while reducing consumption of natural resources.

5. OPERATION & UTILIZATION

Key parameters that measure the life of an asset include tracking the age, depreciation, performance (and frequency of downtime), maintenance costs, overall support from the manufacturer, storage in terms of real-estate value and utilization rates. We must also consider qualitative data as well, like end-user satisfaction, effectiveness, and facilitation of workflow. Organizing this information will provide the quantitative and qualitative information needed to evaluate future equipment investment decisions and ROI.

6. END OF LIFE EVALUATION

Determining which retirement phase is approaching — end of service/OEM support, end of use or complete depreciation — in conjuction with the category of the waste and material composition will help determine the best path for the equipment retirement plan and the most appropriate method of sorting. For equipment with computer components, an extra layer of complexity involves how the patient data and security will be managed and must be factored in each of these retirement decisions:

- ***Trade-in.*** Work with the vendors for decommisioning, trade-in and upgrade opportunities.
- ***Repair & Refurbish.*** Salvage parts that are useable and replace the parts that are obsolete. Partner with OEMs and biomedical technicians endorse restoration and have developed programs to support refurbishment
- ***Re-sell.*** Platforms like Rheaply (U.S.) and Health Share (Canada) help connect facilities with exchanging resources and medical equipment that have reached depreciation or still have use.
- ***Donate.*** Non-profits like Project C.U.R.E, Medical Bridges and MedShare facilitate the logistics of collecting and distributing surplus or unused medical supplies and equipment from healthcare facilities who have a desire to contribute to a charitable cause for the local and international communities.
- ***Recycling & Re-processing.*** Although there are costs associated with extraction and upcycling, this method can salvage 70% or more of equipment from disposal, and generate income for jobs required to re-process and operate recycling facilities.
- ***Disposal to Landfill.*** The remaining components may be incinerated or dumped in landfills, but with the help of recycling and re-processing facilities, it is possible to attain goals like 80 to 100% recovery, or zero waste.

A Cultural Shift in Conservation

Many businesses look to the healthcare industry for examples of leadership, progressiveness, and community. The concept of circular economy is a mindset we all should adopt. It is an attainable goal if we start building the proper habits today when planning for the future. The information we uncovered sparked our urgency to bring awareness of this trend and continue the conversation with like-minded professionals to find solutions for healthcare sustainability. The U.S. is ranked as one of the largest waste producers globally, but we can make the decision to alter this path by examining countries that have started implementing successful sustainable practices and establish our own regional standards to regulate hazardous waste. Something simple like developing a committee within your organization with specific goals and programs in your facility is an impactful endeavor. As we redefine the life cycle from environment extraction to planetary depollution, we are taking the first step in creating a cultural shift to see everything we interact with as circular.

ABOUT THE AUTHOR

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Bukola Jaji is the senior medical equipment planner for Blue Cottage of CannonDesign consulting firm. Her compassion for quality of life motivates her to serve the community and empower individuals to collaborate to find solutions. She has her bachelor's in biomedical engineering from Vanderbilt University and master's in engineering management from University of Texas - Austin.

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Rupa Kango is a senior healthcare planner and an architect with CannonDesign. With over 14 years of experience, she has worked on many different healthcare typologies. She is passionate about designing healing spaces and developing ideas that respond holistically. She holds a master's degree in architecture from Texas A&M University with Certification in Health Systems and Design along with been a licensed architect, LEED AP BD+C and RELi AP.

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