Avantor Services

Sustainability by design: considerations for the lab of the future

PREFACE/ABSTRACT

For most large corporations and universities, sustainability has now become a priority at the highest levels of leadership. While many scientists strive to reduce, reuse and recycle waste at home, it is often more challenging to adopt the same practices in our laboratories. R&D is an intensive process and labs consume a disproportionate amount of resources[1] and produce waste in significant quantities. The mounting concerns about the long-term impact of human activity on the environment calls for deploying a holistic sustainability strategy.

Fortunately, lab sustainability programs need not be considered only as an operating cost. Many lab companies and organizations invest in ways to improve inventory, chemical and equipment management in order to reduce costs, eliminate redundancies and inefficiencies across multiple labs and operating sites. They are discovering that these efforts reduce waste as well — good operating and procurement practices can contribute substantially to incorporating sustainability as well. These efforts can ultimately enhance lab efficiency and return time back to science.

INTRODUCTION: TOWARD THE SUSTAINABLE LAB

The world's resources are limited and, over the next few decades, the demand for energy, clean water and other natural resources is certain to increase. There is an expanding body of evidence that climate change will have significant impacts on people and businesses within our lifetimes[2]. The environmental changes observed by researchers over the past several decades are not fully explainable by natural climate variability models[3].

Scientists and researchers are acutely aware of these facts and are passionate about environmental consciousness and responsibility. Lab managers need to strike a difficult balance: making sure their researchers have the best equipment and resources to do the best science while advancing sustainable operations. One way to accomplish this goal is to base their procurement and materials and equipment management decisions on what best contributes to sustainability.

Scientific labs are heavy resource consumers and produce significant quantities of environmentally impactful waste – including a broad range of commonly disposed materials, such as plastics, paper and cardboard packing materials. Gaining control over these wastes is now considered a top environmental priority. For example, lab-generated plastic wastes include a wide variety of single-use consumables, like pipette tips, syringes, gloves, cell culture consumables and associated shipping and packing materials.

Chemical wastes include used solvents, specialty chemicals, expired lab reagents and spent radioactive substances. A shift to sustainable "green" solvents is now a major focus for many due to an increasing awareness of the heavy impact of solvents on pollution, energy usage and contributions to air quality and climate change.[4]

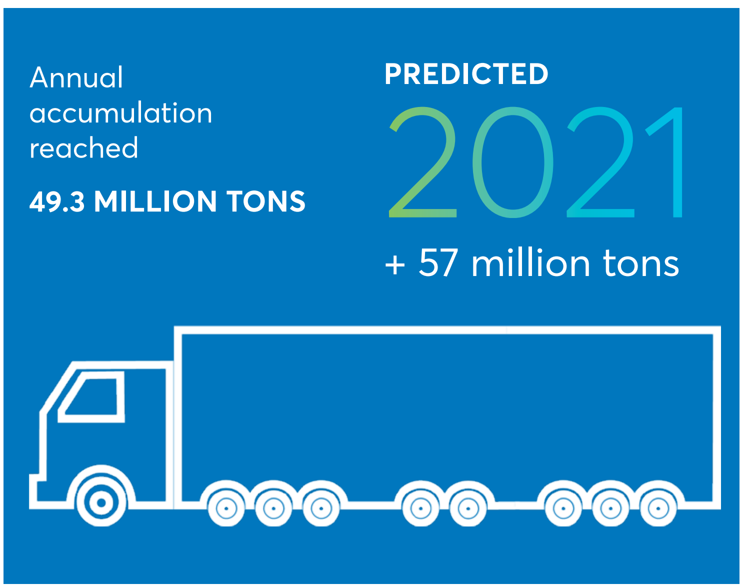
E-waste has become the world's fastest growing trash stream and includes items such as computers, monitors, printers, mobile devices, lab equipment and anything else with a printed circuit board. Labs are increasingly reliant on automation and digital (connected) devices. To keep pace with advances in technology, the continuous upgrading of these types of equipment translates into large quantities of e-waste created by our labs.

Global accumulation of e-waste has more than doubled in the last nine years. In 2016, according to the United Nations University which is a global think tank that tracks the problem, the annual accumulation reached 49.3 million tons, enough to fill more than a million 18-wheel trucks. By 2021, the annual total is predicted to surpass 57 million tons.[5]

Labs also have substantial energy costs driven by the widespread use of low-temperature freezers, advanced ventilation systems and lab instruments that idle in a constant state of readiness. On any given campus, academic or commercial, the labs are responsible for most of the energy consumption and waste production.

There are efforts across the industry, particularly in the architectural and interior design communities, to increase energy efficiency within their designs. However, some sustainable design elements are hard to incorporate into the laboratory environment since their application can counter existing, preferred operational practices. Architects, laboratory planners and engineers must be adept at translating a company's vision for sustainability into a viable and attractive laboratory design solution.[6]

Fortunately, senior executives in both the public and private sectors are now prioritizing sustainability in the boardrooms. Similarly, a growing number of scientific leaders are making a point to become more mindful about their lab waste streams, water consumption and energy use.



GLOBAL LEADERSHIP, GLOBAL SCALE

What will drive the necessary efforts to evolve lab practices and operations to be more sustainable? In response to community concerns, government regulations and encouragement and pressure from the investing community, many major government and university research operations and life sciences companies are setting broad, long-term goals at the highest levels to reduce waste with organization-wide metrics, such as:

- Zero waste to landfills
- Specific annual percentage reductions in water, energy and waste
- Quantifiable reductions in carbon footprint

In addition, a growing number of scientific leaders are making a similar point to become more mindful about their lab waste streams, water consumption and energy use. The core challenge for lab operations is finding ways to quantify and track how their specific activities and changes can be effectively scored and rolled up through their organizations to demonstrate contribution toward these and other goals — with verifiable, repeatable data.

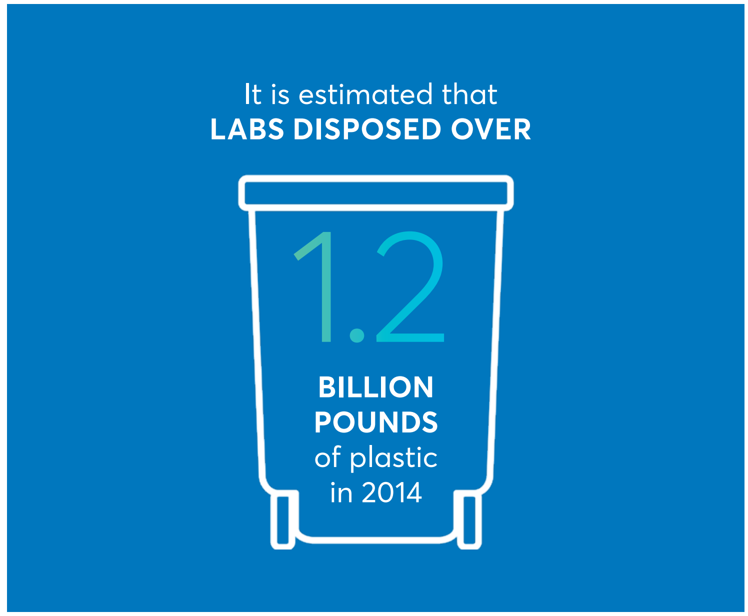
One of the key challenges is the sheer size of these organizations: One leading global biopharmaceutical company has 6,000 people working in 52 buildings on just one of its research campuses — with other locations of similar size. And it is well-recognized that these research organizations are more fragmented and less centrally managed, compared to other industries, with individual labs often operating and managing materials and equipment acquisitions independently of each other.

REACHING SUSTAINABLE "GOLD"

One lab management team at a European biopharmaceutical research lab worked with My Green Lab, a non-profit organization dedicated to improving the sustainability of scientific research in reducing multiple waste streams. The lab management team received the organization's Gold accreditation level. Ways they reduced waste included:

- Using existing company databases to identify existing, available equipment before purchasing new equipment
- Investing in programs to recycle CAT-1 nitrile gloves rather than dispose of them
- Recycling Winchester glass jars with plastic lids instead of disposing of them
- Installing timer plugs/turning lab equipment on nights and weekends

Long-term, the lab engages in continuous efforts to save more resources and is working to share their techniques with other labs.



PLASTIC AND PAPER WASTE

Scientists are referring to the current geologic epoch as the Anthropocene, based on when humanity made a significant impact on Earth's geology and ecosystems. And it's possible that after the Bronze and Iron Ages, the current period may become known as the Plastic Age.[7] The amount of plastic trash streaming into the oceans is roughly the equivalent of a full garbage truck every minute, according to a 2016 report by the World Economic Forum.

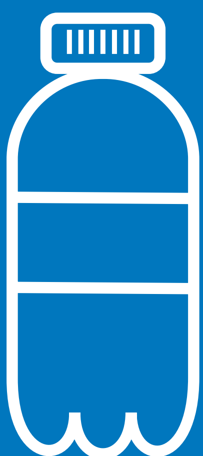
It's estimated that 79% of the plastic produced over the last 70 years has been thrown away, either into landfill sites or into the general environment. Just 9% is recycled with the rest incinerated.[8] Life science researchers are far from innocent when it comes to contributing to the plastic waste problem.[9] In 2015, researchers from the University of Exeter in the U.K. reported that the 280 bio scientists working in their labs generated roughly 267 tons of plastic waste during the prior year — just under one ton per scientist.

It is also estimated that labs disposed of over 1.2 billion pounds of plastic in 2014, not including gloves, hazardous waste and packaging materials.[10]

A parallel waste challenge for many labs is paper and packaging waste. One life sciences research establishment determined that it generated 950 tons of paper packaging annually across the site. That's more than 3 Boeing 747-8 aircraft stacked on top of each other.

All the blue recycling bins scattered around lab workspaces cannot substitute for finding ways to reduce the actual volume of paper material. Not only is this waste itself a product that has a carbon cost; the carbon footprint is increased by collecting and transporting it to recycling facilities or landfills.

Recycling has challenges, especially for plastics. Today, the small percentage of plastics actually recycled usually get turned into products considerably less valuable than the original.[11] Experts believe that the long-term solution is developing plastics that are either biodegradable or designed for "chemical recyclability."



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WASTE CHALLENGE
for many labs is paper and packaging waste

Chemical recyclability yields polymers identical to the originals, rather than downcycling through open-loop recycling. Chemical recyclability is restorative and regenerative by design and aims to keep materials at their highest utility and value.

Conversely, an open-loop recycling process is one where waste is treated using various methods, such as heating, chemical reaction or physical crushing. The recycled product is of lower value and can't be recycled again; today, nearly all plastic recycling is open-loop type.

A more sustainable approach is to reduce the type and amount of waste materials coming into the lab in the first place. Although single-use systems are growing in many life sciences labs and production environments, a more organized and consistent analysis of the plastics and paper coming in offers opportunities to change procurement patterns.

Reducing packaging waste is an ongoing challenge — and one that many lab managers don't have the leverage or time to pursue since it's ultimately up to the manufacturer to find ways to make their packaging more sustainable. Organizations that provide turn-key solutions in lab supplies, equipment life cycle, bio-sample, chemical and solvent management, like Avantor Services, do have that leverage.

They can work with suppliers to find simple ways to reduce packaging material that's wasted. At the same time, they can help labs shift to centralized stockroom and just-in-time replenishment models: Instead of every lab ordering 50 syringes in 20 boxes, a central storeroom orders one box of 1,000 and supplies each lab with the materials as needed.

Digital technology offers another avenue for paper waste reduction. For example, paper can be replaced by digital tools for record-keeping and lab management purposes. Electronic calibration certificates replace paper documents, so that periodic file dumps don't fill up landfills. Managers and lab services personnel use smartphones to scan shelves and input restock orders, rather than paper forms on clipboards that are tossed once the task is complete. Digitalization can also reduce paper waste by making the process of inventory data capture and reordering more accurate, reliable and ultimately repeatable, thus eliminating the need to use more forms for follow-ups and inventory reconciliation activities.

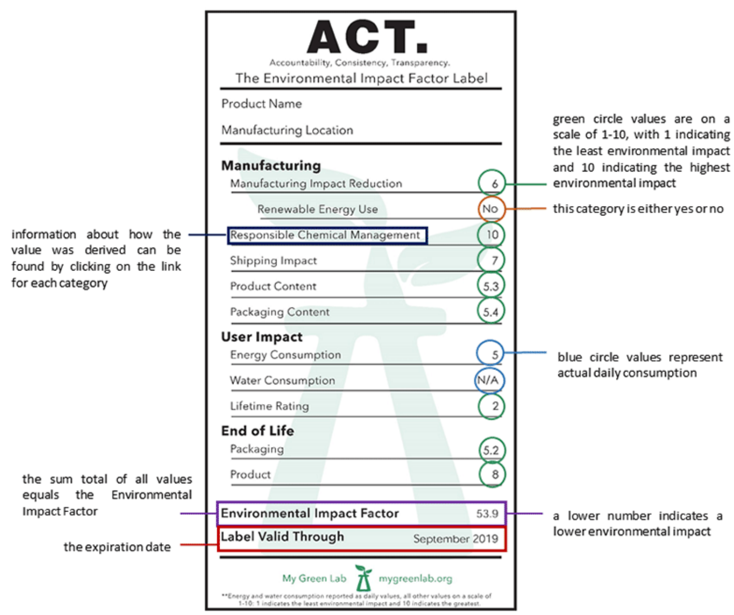
Many of these efforts are already underway to help reduce costs and redundant ordering, through inventory management, chemical management and equipment management programs. However, these efforts need to expand; equally important, sustainability data needs capturing to help identify how these efforts quantifiably contribute to more sustainable labs. This means having the expertise to investigate where plastic waste comes from, quantify the volume and determine how recyclable it is, as well as working with suppliers to make their products more sustainable.

One important way that professional, on-site lab inventory and supply management organizations can help improve sustainability is through their connections with, and insight into, the practices of a wide range of third-party service providers. These vendors — equipment suppliers and servicers, vehicle management, waste removal — all carry out activities that have an impact on a lab's waste stream, energy consumption and sustainability efforts.

Professional lab management companies have the responsibility to look at a lab's complete process — products, procurement, inventory, usage, optimization of tasks, waste and recycling procedures and so forth. It also supports tapping into the vendor/supplier base to better help labs implement an integrated sustainability initiative.

THE ACT LABEL

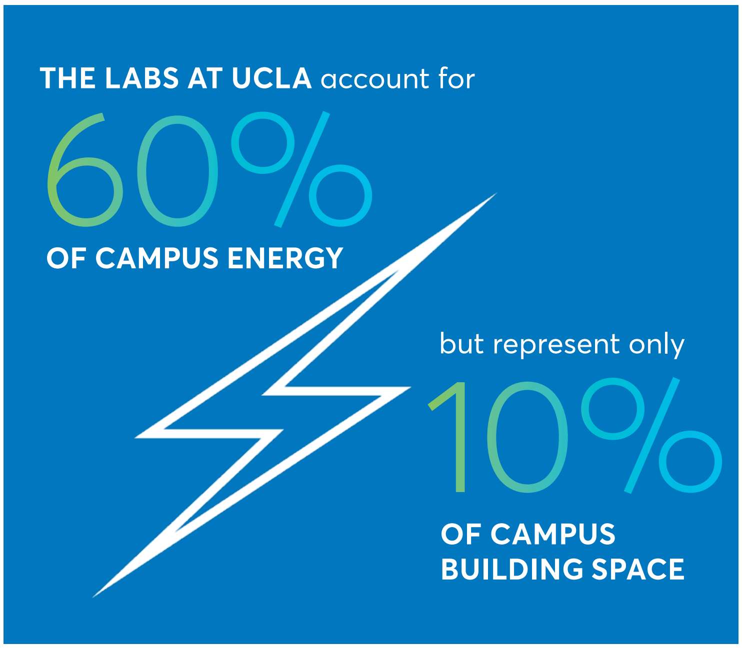
One valuable tool to help labs make smarter, more sustainable purchases is the ACT Label. It is the premier eco-nutrition label for laboratory products, including consumables, chemicals and equipment. The criteria for the label, developed with industry input, is called the Environmental Impact Factor and scores a product's environmental impact during manufacturing, use and eventual disposal/end of life. Through its Environmentally Preferable Products program, VWR, part of Avantor, offers a wide range of products that carry the ACT Label. For more information, visit **us.vwr.com/cms/sustainability_environmentally_preferable_products**.

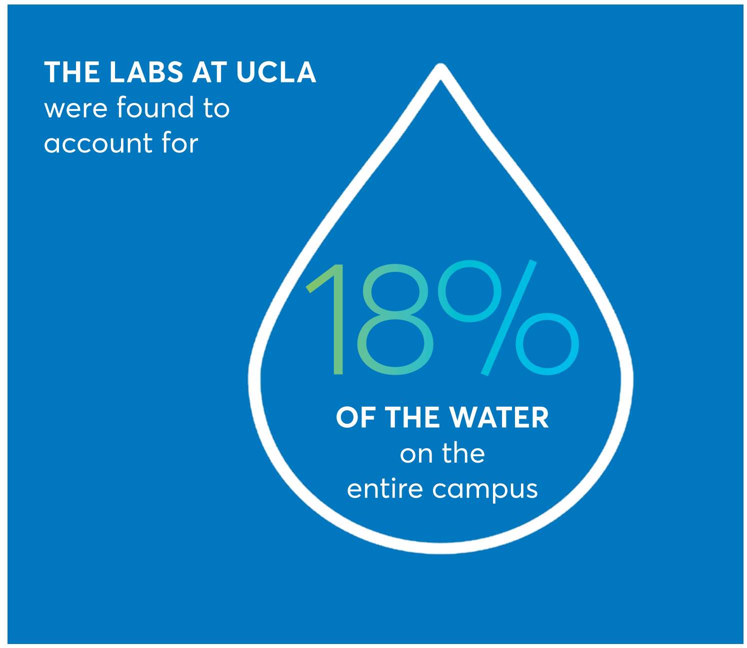


ENERGY AND WATER CONSUMPTION

Laboratories are notorious for their energy appetite, often using six to 10 times the amount of energy of an equivalent-sized office facility. The Office of Environmental Health & Safety at UCLA recently reported that their labs account for 60% of campus energy demand but represent only 10% of campus building space.[12]

Water usage in labs can also be extremely high. Laboratories can consume water for cooling equipment and sanitization of glassware and a variety of other items. In a 2010 study conducted at the University of California Berkeley, labs were found to account for 18%





of the water consumed by the entire campus, which includes the residence halls, classrooms, office buildings and landscape uses.[13]

Several effective approaches have demonstrated that leveraging Internet of Things (IoT) technologies raises the visibility of water and energy consumption habits with end-users. In a recent study at Harvard Medical School's Drosophila RNAi Screening Center, one lab demonstrated energy reductions averaging 51% utilizing their energy-intensive lab equipment through the use of "smart plugs" and employing social engineering techniques to change lab behaviors.[14]

Changing water consumption patterns – and documenting water and energy savings – is another area that many labs could investigate. One research organization considered outsourcing all its glass washing and sterilization processes. The outsourcing organization found ways to upgrade the equipment and processes used when reducing the use of clean water and electricity – while also improving costs.

Cold storage of samples is another significant energy use for many labs and research facilities. The energy consumption related to the standard compressor-based ULT freezer is comparable to that of an average U.S. household.[15] Lab management programs that reinforce the need for labs to defrost their freezers, clean out or consolidate samples and tweak the temperature from -80°C to -70°C can significantly reduce energy use.

In addition, the ENERGY STAR® rating is a widely known energy-efficiency label from the U.S. Environmental Protection Agency and the Department of Energy. ENERGY STAR ratings are now available for -80°C and -20°C freezers.

As the demand for biospecimens in research is expected to increase exponentially, the need to store and manage them efficiently and effectively will, too. Proper attention must be given to the associated energy utilization and the development of smart sample storage strategies that take the equipment life cycle, lab space and energy consumption into account.

The energy used by [plug-in] laboratory equipment (e.g., freezers, autoclaves, centrifuges) constitutes from 10% to as much as 50% of the total energy use in a laboratory (not including associated cooling energy use).[15] And many labs often have duplicate pieces of equipment – costly and heavy energy-users – in different labs at the same site, sometimes on different floors in the same building. By working with an equipment management services provider, this duplication can be dramatically reduced, and many forward-thinking labs are doing so to reduce excess equipment costs. But labs that undertake lab space-sharing arrangements, or organizations that implement in-house equipment inventory websites to let lab managers know when a needed machine is available, can prevent the added electricity consumption burden.

The Smart Building movement, which also uses IoT-type environmental control technology, is another source of quantifiable energy savings. Inexpensive wireless sensors of many types can capture massive amounts of real-time data for analysis and optimization of building systems, including water, lab ventilation, HVAC and lighting.

(PLUG-IN) LABORATORY EQUIPMENT
energy use constitutes from

10-50%

OF THE TOTAL ENERGY USE IN LABS

CHEMICAL WASTE

Few laboratory researchers will question the need for hazardous materials in certain experimental procedures. But the disposal cost of such materials now routinely exceeds their purchase price – and this cost continues to rise. The tightening of federal, state and local regulations aimed at protecting people and the environment are driving up costs associated with the transport and handling of all types of hazardous lab waste. For example, the University of South Florida System reported in 2015 that it disposes more than 100,000 pounds of hazardous waste per year at a cost to the university of more than $150,000 annually.[16]

Large universities and private research centers typically have thousands of different chemicals that are used and stored across hundreds of labs, clinics and stockrooms. An essential component to waste minimization is an accurate, online chemical inventory. Labs can avoid duplicate purchases by knowing what chemicals are already on hand. Many research chemicals are only used in small quantities and have a significant shelf life, making sharing between labs very practical.

Sometimes, this can go against ingrained habits by researchers. Believing they're saving money, some researchers purchase the large bottle of solvent or salts for their specific lab even though they only need a smaller amount for their work. Ultimately, the sustainability impact can be negative. If the large bottle sits on the shelf until it expires, then it's even more costly to safely dispose of it.

Several leading life sciences companies are building sophisticated online tools to make obtaining a wide range of chemical consumables, intermediates and compounds easy. This is especially helpful for projects that need small amounts of product – one gram, 10 grams, etc. Rather than spending time and consumables to create an intermediate or compound, searching for and getting that same product delivered is much more sustainable.

Chemical purchases can also be reduced, thereby making central chemical storage schemes self-funding through the savings created by duplicate purchase avoidance and waste disposal cost savings. Regulatory guidance further emphasizes the importance of rigor in the management of lab chemical inventories as part of lab occupational health and safety programs.[17]

The use of "green solvents" for extractions, separations and chemical reactions has become an increasingly important topic of interest to many scientific lab groups.

Several general-purpose solvent selection guides have now been published with the aim to reduce the use of the most environmentally impactful solvents.[18]

CHEMICAL MANAGEMENT

A large biopharma research facility working with Avantor Services created a clear and simple yet flexible chemical handling process for the whole site that was well-suited for future needs and provided fast deliveries of bulk, solvent and special chemicals.

Centralized stockroom managed by one team:
- Easy and intuitive search function and automated purchasing
- Simplified and standardized delivery
- Reduced number of chemicals stored/storage sites
- Helped control costs

COLLABORATE & DEVELOP	MANAGING YOUR SUPPLY CHAIN	TECHNOLOGY & ONSITE SOLUTIONS
DEVELOPMENT **INNOVATION CENTRE** – Custom chemicals – Process optimisation – Custom packaging – Lab or production scale	**DISTRIBUTION** **SUPPLY CHAIN EXPERTISE** – Chemical storage – Spend management – Change notification	**CHEMICAL MANAGER PLATFORM** **COMPLETE VISIBILITY** – Track all chemicals across multiple locations – Manage chemicals from any supplier – Configurable to your process – Simplify data and analytics
CGMP MANUFACTURING **PRODUCTION FACILITIES** – Chemicals to biologics – Custom delivery solutions – Custom packaging	**INVENTORY MANAGEMENT** **ONSITE SUPPORT** – Lean Six Sigma process improvements – Receiving, barcoding and distribution to points of use – Tracking of chemicals from any supplier – Metrics, data and compliance support	**DISPOSAL** **SAFETY AND COMPLIANCE** – Entire waste life cycle solutions – Sustainable and compliant

ELECTRONIC WASTE

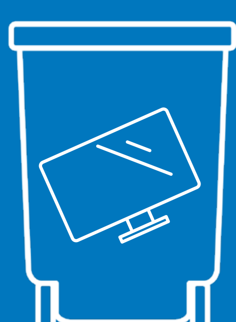
Electronic waste (e-waste) has become the world's fastest-growing waste stream: According to the United Nations University, a global think tank that tracks the problem, the yearly accumulation of e-waste reached 49.3 million tons in 2016, enough to fill more than a million 18-wheel trucks. By 2021, the annual total is predicted to surpass 57 million tons.[19] E-waste is a major contributor to pollution problems worldwide due to the presence of toxic substances that contaminate the environment. Several tools have been developed to better manage e-waste, including life-cycle assessment (LCA), material flow analysis (MFA), multi-criteria analysis (MCA) and extended producer responsibility (EPR).

There are several keys to success in terms of e-waste management. These include the design of electronic devices for easy recyclability, proper collection of e-waste, disposal of e-waste by suitable techniques, prohibiting the transfer of used electronic devices to underdeveloped countries and raising end-user awareness of the environmental impact of the e-waste they generate.[20]

E-WASTE
predicted to be

57 million tons

BY 2021



The dynamics for reducing e-waste are very similar to those associated with reducing equipment energy waste: information across the organization that makes equipment no longer used by a research team or lab available to others in the organization.

A common situation in many life sciences organizations is equipment waste related to changes in research programs or facilities planning. When a research project or program comes to an end, or an organization decides to redeploy researchers to new projects or combine research teams in one facility, buildings get cleared out. There is often little effort to reuse equipment and make it available within the organization – particularly when centrifuges, electronic scales and worktop computers are older.

Comprehensive equipment management programs can prevent this from happening – not only saving costs but also making sure useful equipment is used rather than thrown out, thus purchasing new equipment. It provides a significant contribution to sustainability and such programs provide ways to track and quantify the sustainability benefit.[21]

Lab Instrument life-cycle management (LCM) programs should include a comprehensive asset recovery component. These programs gauge equipment acquisition and disposal timing based on utilization, functionality, new equipment introductions, used equipment values and sustainability factors.

Rapid advances in scientific instrumentation will continue for the foreseeable future, and labs will be challenged in managing their scientific instrument life cycles. Implementing a comprehensive LCM program enables companies to both optimize scientific instrument investments while ensuring the environmental impact is minimized through thoughtful recycling and redeployment strategies.

SUSTAINABLE PROCUREMENT PRACTICES

Unfortunately, many science organizations find themselves caught between social responsibility and economics. Scientists working in the lowest cost at-all-cost operations are frequently forced by procurement policies to make buying decisions that violate their own personal sustainability and social responsibility beliefs.

Strategic sourcing efforts must transform quickly to prioritize the "greening of the supply chain," not just when it is the lowest cost alternative at the item level. A crucial first step is the development of effective sustainability metrics to enable cost-benefit comparisons that consider sustainability equally alongside item-level cost.

While individual organizations and companies have begun developing their own metrics for measuring their current state of sustainability and then documenting their improvements, no real-life science, industry-wide standards have been created. Imagine if every country had a different way of measuring temperature. (We still operate with two and have to regularly convert from Fahrenheit to Celsius and back.) Constantly converting different temperature scales, rather than using a common one, makes it much more difficult to make decisions about technology and processes.

There has been some progress toward common agreements regarding how to measure CO_2 reductions by modifying how often goods are shipped and by what method (aircraft, ocean, rail, etc.). However, a standard set of metrics globally for all aspects of sustainability would build engagement across the supply chain.

Fortunately, the practice of "sustainable procurement" is a growing industry trend that helps organizations focus on the concept of the "triple bottom line" of spend management, social responsibility and sustainability.[22]

There is an incremental cost to becoming more sustainable, some of which can be offset by reduced waste and the costs of recycling and disposal. There are also costs to defining and implementing the sustainability practices, which includes suppliers having a clear understanding of the costs companies are willing to pay for more sustainable products – and those companies actually defining what they need.

It also calls for better communication about the choices that companies have, including leveraging tools like the ACT Label to clearly identify products that are objectively assessed as being more eco-friendly; this includes efforts to educate lab managers on the details so they can make informed procurement choices.

Centralized inventory, equipment and chemical management programs, conducted by experienced logistics and purchasing organizations, can do more than reduce or eliminate redundant and wasteful lab purchasing and supplies management processes. They can also build into their processes tools that track the sustainability contribution their procurement processes make on a lab-by-lab basis, if necessary.

These programs can be flexible and scalable, rather than "one size fits all." Depending on the amount of inventory consumed, the rollover of equipment and the diversity of chemicals used by a given lab, sustainability initiatives can be integrated into existing procedures, or added as part of a new professional lab services solution. Sustainability — just like cost reduction, reduction of redundant purchases, stock turnaround times and other more traditional measurements — becomes a standard set of metrics by which to evaluate the performance of a professional lab management organization like Avantor Services.

CONCLUSION

The long-term impact of human activity on the environment is rapidly becoming evident. Scientific research and development is an intensive process and our labs consume significant resources and produce environmentally significant waste in large quantities.

Many scientists are passionate about reducing their carbon footprint, acting in ways to improve the environment and leaving the world a better place for future generations. Many are eager to respond to the calls from the C-suite to make their lab operations more sustainable and less wasteful. Scientists are also data-driven: They seek demonstrable measurements of how the products they purchase and the procedures they follow contribute to sustainability.

The scientific community must come together to not only contribute but to also lead sustainability efforts, driving the development of new best practices and rethinking organizational policies and procedures related to waste reduction and environmental sustainability.

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ABOUT AVANTOR SERVICES

Avantor Services is the industry leader in laboratory facility and technical, scientific services with over 2,000 highly skilled associates deployed across the US, EU and Asia. We provide turnkey solutions in lab supplies, equipment life cycle, bio-sample, chemical and solvent management that help labs run more efficiently, effectively and sustainably. Our technology development teams build industry-leading systems that leverage the latest technological innovations, including IoT and AI, to reduce operating overhead costs and drive excellence in sustainability. Our skilled sustainability consultants can work with your labs to help you achieve your sustainability objectives.

Please visit our website at: **avantorsciences.com/avantor_services** to learn more about our sustainability services and read success stories about how Avantor Services is leading sustainability efforts in Scientific Research and Development labs around the world.

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