LIFE SCIENCES

Insights

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BUILDING A GREENER FUTURE: SUSTAINABILITY IN LIFE SCIENCES

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Dear Reader,

SUSTAINABILITY IS NO LONGER A NICE-TO-HAVE IN LIFE SCIENCES. IT IS A STRATEGIC PRIORITY THAT IS SHAPING HOW WE DISCOVER, DEVELOP, AND DELIVER SCIENCE. AS AN INDUSTRY FOCUSED ON IMPROVING LIVES, WE ALSO HAVE A RESPONSIBILITY TO MAKE SURE THE WAY WE INNOVATE SUPPORTS THE HEALTH OF OUR COMMUNITIES AND THE PLANET.

This issue of Life Sciences Insights explores how sustainability and science are deeply connected. From reducing plastic waste and rethinking lab operations to designing flexible facilities and increasing energy efficiency in manufacturing, life sciences organizations are proving that sustainability drives more than environmental benefits. It leads to stronger operations, smarter systems, and long-term resilience.

Life sciences is built on data, precision, and progress. That same mindset is what makes us uniquely equipped to lead on sustainability. With the right tools and partnerships, we can reduce emissions, improve supply chains, and minimize waste while continuing to accelerate breakthroughs for patients.

We hope the ideas in this issue spark new conversations, surface practical strategies, and inspire more action. Because the future of life sciences will be defined not only by what we cure, but by how we care for the world around us.

Katie Kiss
Senior Director, Marketing
California Life Sciences

ASTRAZENECA: PIONEERING SUSTAINABLE HEALTHCARE

Submitted by AstraZeneca

ASTRAZENECA, A GLOBAL LEADER IN PHARMACEUTICALS, IS TRANSFORMING HEALTHCARE WITH A STRONG COMMITMENT TO SUSTAINABILITY. DEDICATED TO INTEGRATING SUSTAINABLE PRACTICES ACROSS ALL OPERATIONS, ASTRAZENECA IS NOT ONLY DRIVING MEDICAL INNOVATIONS BUT ALSO ENSURING THAT THESE ADVANCEMENTS ARE ENVIRONMENTALLY RESPONSIBLE AND BENEFICIAL TO SOCIETY.

A COMMITMENT TO SUSTAINABILITY

AstraZeneca's sustainability principles are evident in its two San Francisco Bay Area sites: a research and development center in South San Francisco and a manufacturing facility in Redwood City. Despite their different roles, both locations share a unified vision for sustainability.

SOUTH SAN FRANCISCO: A MODEL OF EFFICIENCY

The South San Francisco site is a testament to AstraZeneca's dedication to environmental responsibility. Designed to maximize efficiency and sustainability, this facility has earned the prestigious LEED Platinum certification, underscoring its commitment to reduced environmental impact and operational costs. Key features include natural light integration for energy conservation and employee well-being, indoor vegetation for

air quality enhancement, and open spaces that promote physical activity. Through events like Earth Day celebrations and green initiatives, the South San Francisco site nurtures a culture of sustainability among its employees, a sentiment shared across all AstraZeneca facilities.

The site has also excelled in sustainable scientific practices. Collaborating with My Green Lab (MGL), AstraZeneca's South San Francisco facility was the first to achieve a Green rating, the highest honor, in 2020, and has consistently maintained this status. Participation in the MGL International Freezer Challenge has further cemented AstraZeneca's sustainability credentials, with notable awards from 2020 to 2024. Initiatives such as glove recycling with RightCycle and tip box recycling with Terracycle promote sustainable laboratory practices.

In 2021, the site achieved TRUE Platinum level certification for zero waste, a remarkable accomplishment for a combined office and lab space. Key strategies included dedicated recycling and compost bins, comprehensive training, and sustainable catering practices.

With procedures promoting the use of compostable utensils and packaging, AstraZeneca has significantly reduced pantry waste, exemplifying its dedication to sustainable resource management.

REDWOOD CITY: EXCELLENCE IN ZERO WASTE

The manufacturing site at Redwood City has also succeeded in implementing sustainability initiatives, also attaining Green status within My Green Lab. Through programs like SWOOP (Switch Off Optimization Program) and HVAC optimizations, AstraZeneca has avoided more than 5,000 MWh/yr of energy use. Furthermore, the site has made impressive strides in waste management, saving significant amounts of waste through recycling & bulk purchasing. For example, by transitioning to electronic documentation and inventory systems in 2018, Redwood City saves more than 15,000 sheets of paper annually.

Water conservation efforts included replacing single-pass cooling systems and installing low-flow taps, avoiding over 11,000 kL of water annually.

CONCLUSION

Both the South San Francisco and Redwood City sites exemplify AstraZeneca's integrated approach to sustainability, demonstrating that environmental responsibility is a shared mindset across diverse operational functions. By fostering innovation through sustainable practices, these sites collectively contribute to AstraZeneca's mission of reducing environmental impact while advancing healthcare. As leaders in creating a sustainable future, AstraZeneca stands at the forefront of addressing global challenges like climate change, health equity, and system resilience, underscoring its role as a responsible and visionary healthcare leader. ■

DEPLOYING A CIRCULAR ECONOMY FOR MEDICAL DEVICES

Submitted by Grace Lillie, Mechanical Engineer | Battelle

SUSTAINABILITY AND ESG INITIATIVES HAVE ALL TAKEN CENTER STAGE IN THE NEWS AND CORPORATE STRATEGIES, OFTEN LEAVING ORGANIZATIONS UNCERTAIN ABOUT HOW TO NAVIGATE THE COMPLEXITY OF IMPLEMENTING GREENER PRACTICES.

In healthcare, the one-time-use model is even more glaring. Individuals with diabetes and insulin therapy require frequent use of medical supplies such as sharp needles, plastic syringes, injector pens, and glass vials.

In the United States alone, it is estimated that over 7 billion insulin pens, needles, and syringes are discarded annually.

A complex regulatory landscape means implementing waste reduction strategies in healthcare is not as simple as it may seem. Patient safety, including cross-contamination and biohazard risks, has influenced the infrastructure and systems in place today.

Not only that, but reusable devices are an investment. Once used, they require additional steps to be reprocessed. During this time, devices are collected, transported, sterilized, and assessed for sterility assurance. This process can be timely but also financially not feasible given additional devices must be purchased to cover gaps in sterilization processing workflows.

Many medical devices are not designed to withstand sterilization processes, creating product-performance issues once reprocessed. Combined with the added expense of replacing damaged products or degradation, single-use devices can often be the most economical choice.

These limitations mean that in many cases, manufacturers will design medical devices to be thrown away.

THE BENEFITS OF A CIRCULAR ECONOMY

The traditional, linear model of "take-make-dispose" takes raw materials and turns them into goods that are later discarded. This system is full of inefficiencies, depletes valuable natural resources, and creates mountains of waste in landfills.

Enter the circular economy. The circular economy is an approach to resource management that prioritizes sustainability throughout the supply chain. The core principles are to eliminate waste, circulate products and materials, and regenerate nature, establishing a closed-loop system.

Establishing a circular economy has a host of financial and environmental benefits. Some may be more obvious than others.

A circular approach can lead to reduced carbon emissions, enhanced resource efficiency, and less medical waste in landfills.

There is also a cost-savings element. A single, upfront investment in raw materials drives down the long-term cost-per-use of the finished good.

STRATEGIES FOR CHANGE

Battelle has taken a holistic approach to medical device design for decades. We can leverage our expertise in chemistry, materials science, and human centered device design and development to support your eco-design initiatives while meeting performance and quality standards. Here are six tactics to consider as you move from a linear approach to a circular economy.

REFUSE

Sometimes products don't need to be purchased in the first place. Implementing procurement strategies that favor environmentally friendly materials circumvents the need for disposal.

REDUCE

One of the core tenets of the Three R's, a conscious effort to reduce the number of materials used in the manufacturing process lowering the carbon footprint and energy use. Finding ways to combine disposable components with reusable devices is another way to implement this strategy. Reducing packaging materials is another significant opportunity and can be easier than reducing device materials.

REUSE

In the most basic terms, this means reusing something as many times as possible before throwing it away for good. Of course, it's not always that simple, especially when managing medical devices that may be contaminated after use.

The necessary processing involved introduces additional design constraints with material compatibility. There is also a stigma around reusables in certain healthcare settings, with some clinicians considering disposables cleaner and safer.

A full lifecycle analysis is also important here. Reusable products require durable, high-quality materials. It's possible for these types of raw materials to negate any carbon savings. It also opens the door to more nuanced conversations about energy and carbon pollution versus waste and trash pollution.

Additionally, the sterilization and reprocessing of medical devices can result in significant emissions that can outweigh the carbon cost of making a disposable option.

REPAIR/REFURBISH

Criticality and value tend to impact the decision of whether to refurbish or dispose of an item. Repairing and refurbishing are common for high-value equipment like X-rays, MRIs, and ultrasound systems, while low-cost, high-volume items like auto-injectors are more likely to be discarded.

Strategies like product-service systems (PSS), where companies offer both products and servicing, can create value for the customer without increasing the environmental impact.

Renting, leasing, or sharing resources can create sustainable solutions rather than just selling a product or sending it to a landfill.

REPURPOSE

Larger medical equipment can be disassembled, and components can be harvested for use elsewhere. Repurposing can include extracting precious metals from electronics, using reprocessed plastics in new products, and taking functional parts from broken machines for refurbishment.

Products that can't be reused in a hospital setting can also be repurposed for use in laboratories.

RECYCLE

Recycling medical devices into new products comes with additional considerations. Most medical devices are made from a variety of materials. Separating them for recycling is difficult and beyond the capabilities of most United States recycling facilities.

Implementing design for disassembly is a proactive approach but must prioritize safety and user needs.

Recycling also requires manufacturers to develop takeback programs to collect used devices. Successful takeback programs depend upon buy-in from stakeholders, including patients, and often call for additional disinfecting protocols.

HOW BIG IS YOUR FOOTPRINT?

It's important to consider the complete impact of your strategy. Some of the tactics discussed take place outside the direct supply chain, but the impact should not be ignored. Practices like takeback programs and reprocessing involve transportation and energy use that contribute to the environmental footprint of the total value chain.

Their impact is categorized by emission scope. Scopes 1 and 2 are greenhouse gas emissions that are controlled by a company or from purchased energy use. Scope 3 emissions are an indirect result of a company's activities. Since they are so broad and difficult to track, they are often omitted from sustainability goals.

Read our recent blog "Sustainable Development in Drug Delivery Devices" for more.

SUSTAINABILITY IN BIOTECH: HOW LOS ANGELES ADDRESSES ENVIRONMENTAL, SOCIAL, AND ECONOMIC CHALLENGES

Submitted by Biotech Connection LA

SUSTAINABILITY HAS BECOME A KEY FOCUS IN BIOTECHNOLOGY, RESHAPING INDUSTRIES WHILE REDUCING ENVIRONMENTAL IMPACT, PROMOTING SOCIAL EQUITY, AND ENSURING ECONOMIC STABILITY. IN LOS ANGELES, A THRIVING BIOTECH SECTOR IS EMBRACING SUSTAINABILITY TO DRIVE GROWTH AND REGIONAL DEVELOPMENT. THIS ARTICLE EXPLORES HOW THE CITY'S BIOTECH INDUSTRY INTEGRATES SUSTAINABLE PRACTICES AND WHAT THIS MEANS FOR THE FUTURE OF BIOTECHNOLOGY.

ENVIRONMENTAL CONSIDERATIONS

Biotech firms in Los Angeles are implementing eco-friendly practices in raw materials, supply chains, and manufacturing. Companies like OliveBio are developing biodegradable bioplastics, such as polyhydroxyalkanoates (PHA), to reduce the 400 million tonnes of plastic waste generated annually. Meanwhile, initiatives like ALOM's Net Zero Supply Chain and Takeda's Sustainability by Design focus on carbon neutrality, recycling, and material efficiency.

Synthetic biology is transforming drug production by reducing waste and reliance on harmful solvents. Traditional methods produce up to 182 kilograms of waste per kilogram of Active Pharmaceutical Ingredient (API), while bio-based approaches significantly reduce this footprint.

Additionally, decentralized manufacturing cuts transportation-related emissions, enhancing supply chain resilience.

Laboratories are also adopting greener operations. Programs like UCI and Caltech's Green Lab programs and My Green Lab certification promote energy efficiency and waste reduction, addressing the 5.5 million tons of plastic waste labs generate annually.

Corporate commitments further shape the industry's sustainability trajectory. Amgen targets 100% carbon neutrality by 2027, investing $200 million in climate-focused initiatives. AbbVie and Nitto have set ambitious emission reduction goals, with plans for 100% renewable energy and carbon neutrality by 2050. These efforts position Los Angeles as a leader in sustainable biotech innovation.

SOCIAL CONSIDERATIONS

Social sustainability in biotech encompasses community engagement, workforce diversity, and equitable access to career opportunities. The industry offers high-paying jobs, with an average salary of $110,747—significantly above Los Angeles County's median household income of $86,587. Notably, 65% of biotech workers in Los Angeles do not hold a college degree, making these careers accessible.

Programs like SOLA BioInnovation Lab and Women in Bio support diversity by exposing underrepresented students to bioscience careers. The Larta Institute reported that 50% of its 2023 accelerator cohort comprised female founders, with 88% led by diverse entrepreneurs, underscoring efforts to foster inclusivity.

Education initiatives like the Amgen Foundation's STEM outreach, reaching 25 million students in 2023, and Bio-Flex's apprenticeship programs create pathways for underrepresented groups. By investing in these programs, biotech companies ensure a more inclusive workforce while strengthening industry ethics and trust.

ECONOMIC CONSIDERATIONS

Economic sustainability in biotech hinges on long-term value creation, regional growth, and resource management. Los Angeles' biotech expansion is supported by government initiatives like the Los Angeles County Bioscience Initiative, which fosters startups through investment funds and innovation hubs. Key developments include:

- **BioscienceLA:** A regional catalyst supporting startups and collaborations.
- **Biotech investment funds:** A $15 million fund backing early-stage companies.
- **Infrastructure expansion:** Projects like the 15-acre biotech park at the Lundquist Institute and LA BioSpace incubator at Cal State LA.

Los Angeles' New Green Deal aims to create 300,000 green jobs and attract $2 billion in private investment by 2035, reinforcing the city's position as a sustainable biotech hub.

Emerging startups often struggle with funding and expertise. Programs like Larta's Heal.LA (a nine-month bioscience accelerator) and LA BioStart (a five-week bootcamp) provide essential mentorship and training. Public-private partnerships, such as Altasea's ocean research institute, support climate solutions and economic development by fostering innovation.

Collaboration between academia and industry further enhances economic sustainability. Research commercialization from UCLA, Caltech, and USC strengthens biotech firms' R&D capabilities, ensuring long-term stability.

CHALLENGES AND FUTURE DIRECTIONS

Despite progress, several challenges remain:

- **Slow adoption of climate targets:** Only 10% of biotech firms have aligned emission reduction goals with the 1.5°C global warming limit. The industry's overall carbon footprint increased from 3.9% (2021) to 5% (2022).
- **Lack of transparency:** Environmental impact data is available for just 0.2% of pharmaceutical products.
- **Leadership diversity gaps:** Women hold only 22% of CEO roles, while people of color are underrepresented in executive positions. However, companies like Amgen and Gilead are addressing this through targeted hiring and mentorship initiatives.

Regulatory complexity also poses a challenge. Compliance with evolving environmental laws can be costly, but advocacy by groups like California Life Sciences and Biocom California help balance business interests with sustainability goals.

Education plays a vital role in shaping biotech's sustainable future. Universities like UCLA and Caltech offer programs in sustainable business strategy and energy efficiency, training the next generation of industry leaders.

CONCLUSION

Sustainability is becoming a cornerstone of biotechnology in Los Angeles, integrating environmental, social, and economic principles. While challenges exist, the city's biotech sector is making significant strides through corporate commitments, government support, and academic partnerships. As these efforts continue, Los Angeles has the potential to serve as a global model for sustainable biotech, fostering innovation while minimizing environmental impact.

IN PURSUIT OF SUSTAINABLE DEVELOPMENT EXCELLENCE: AN INDUSTRY MODEL

Submitted by Boehringer Ingelheim USA Corporation

THE LIFE SCIENCES INDUSTRY FACES DISTINCT CHALLENGES IN ITS PURSUIT OF SUSTAINABILITY, INCLUDING COMPLEX SUPPLY CHAINS, STRICT REGULATIONS AND THE URGENCY TO COMBAT DISEASES. IMPLEMENTING SUSTAINABLE PRACTICES PRESENTS CHALLENGES AND TRADEOFFS THAT CAN INVOLVE SIGNIFICANT INITIAL COSTS.

Like many companies, Boehringer Ingelheim, a biopharmaceutical company active in human and animal health, encourages employees to contribute to its sustainability efforts. However, tackling industry-specific ESG (Environmental, Social, and Governance) challenges demands cross-functional collaboration, expertise, and strategic alignment.

EMPOWERING SUSTAINABILITY LEADERS

Sustainability is a collective responsibility that also requires knowledgeable, dedicated advocates to lead initiatives to success," said Kelly Rotkewicz, Executive Director of US Sustainability for Boehringer. "We wanted a way to empower our colleagues to become sustainability leaders in their respective domains." To achieve this ambitious vision, Boehringer's US Sustainable Development for Generations (US SD4G) office partnered with the University of Georgia's Terry College of Business (UGA) to create the Sustainable Development Excellence (SDX) Certificate program.

This accredited initiative aims to cultivate internal sustainability leader-champions who can accelerate awareness of its value, educate colleagues on its principles, and identify and implement advances in their departments so sustainability becomes integral to how Boehringer does business. SDX has already delivered substantive benefits: boosting employee engagement, enhancing sustainability practices, and uncovering potential cost and resource savings.

Recognizing the urgent need to accelerate sustainability efforts worldwide, Boehringer and

UGA are sharing the SDX model to help other organizations advance their ESG journeys. “SDX offers a flexible, pedagogically sound template for cultivating informed proponents of sustainability,” said Linda Read, Director of Executive Education at UGA. “It is designed to help graduates engage effectively with and contribute to Boehringer's business and sustainability needs. However, it can be easily adapted to the sustainability needs of other organizations.”

DELIVERING THE PROGRAM

To be considered for SDX, employees in good standing submit applications to the US SD4G office. Thirty-one people were accepted into the 2024 cohort, and all completed the program.

SDX content is rooted in Boehringer’s Sustainable Development for Generations framework, which focuses on three elements: More Health (expanding healthcare access), More Green (championing environmental stewardship), and More Potential (empowering people and communities).

To maximize impact and engagement, the 80-hour SDX program employs a hybrid learning approach that includes live sessions, virtual intersessions, self-paced e-learning, and small-group Sustainable Projects. Each module is co-developed and presented by a UGA faculty member and Boehringer leader-teacher to ensure it is relevant to Boehringer’s business goals and has practical applications. Modules feature foundational learning, useful examples, and engaging application activities. Participants are evaluated on their participation, program evaluations, a knowledge assessment, and Sustainable Project.

A unique feature of SDX is the post-program participant commitment of 80 hours over two years. Graduates agree to assist the US SD4G office through advocacy, communication, education, and project support.

LEVERAGING THE PROGRAM

Christina Gallup, a Quality Digital Applications and Transformation Specialist at Boehringer's Fremont, California, biopharmaceuticals facility, seized the opportunity to join the inaugural SDX cohort. The experience allowed her to hone essential advocacy skills such as effective presentation techniques, delve into sustainability principles and meet colleagues from the Human Pharma and Animal Health groups, who share her passion for advancing human and animal health while protecting the planet.

"SDX's structure offers a unique bridge between academia and industry. It was an effective setup that ensured communication went both ways," said Ms. Gallup.

"It was also useful to hear about the work colleagues across the company are doing that we can apply at Fremont." She cited successful efforts at the Ridgefield, Connecticut site to achieve My Green Lab certification and how Fremont is following suit. "SDX has built a network across the company of people committed to sustainability."

When asked about her progress in her post-SDX advocacy commitment, Ms. Gallup shared, “I have completed about 45 hours so far, including giving presentations and volunteering as part of the More Green and More Health teams onsite. But even when I reach 80 hours, I’ll keep going!”

DELIVERING TANGIBLE BENEFITS

Less than a year since the first SDX cohort graduated, the program has ignited enthusiasm and driven meaningful change at Boehringer. Achievements include:

- **Active promotion:** The 31 SDX graduates have actively promoted Boehringer’s sustainability strategy, organizing events that have reached 4,255 colleagues, achieving a 1:40 reach ratio. • Program expansion: Due to high demand, the 2025 SDX cohort has been expanded to 41 participants.
- **Innovative solutions:** SDX Sustainable Project teams have identified innovative solutions to business challenges, including a $2.1 million savings opportunity, a 10-fold return on the program’s initial investment, and an equipment swap program to reduce landfill waste and save millions of dollars.

- **Future implementations:** Additional solutions identified through the program are expected to come online over the next few months.

LOOKING TO THE FUTURE

"Through SDX, we have begun to create a 'peaceful army' of sustainability advocates," said Ms. Rotkewicz. A second SDX cohort is scheduled from April to June 2025. The US SD4G office is also collaborating with Boehringer's Corporate Headquarters in Ingelheim, Germany to consider scaling the program globally and consulting with regional offices to determine how to adapt SDX for use in their countries.

Boehringer and UGA welcome other companies, academic institutions and sustainability advocates on the journey to create a more sustainable future. For additional details on the SDX model, please contact: **commssd4G.us@boehringer-ingelheim.com** or **expr@uga.edu.** ■

SUSTAINABILITY MOVES SCIENCE – AND US!

Submitted by Eppendorf

IN RECENT YEARS, THE TOPIC OF SUSTAINABILITY HAS INCREASINGLY GAINED IN SIGNIFICANCE, AND IT HAS BECOME A KEY TOPIC WITHIN THE SCIENTIFIC COMMUNITY. THE DEMAND FOR INFORMATION AND DATA ON SUSTAINABILITY IS GROWING RAPIDLY, AND INDUSTRY MUST MEET THIS NEED FOR INFORMATION. IN THIS ARTICLE, YOU CAN FIND MORE ABOUT OUR ENGAGEMENT AS WELL AS OUR CONCRETE MEASURES WITH REGARDS TO SUSTAINABILITY IN THE LABORATORY.

In line with our founder's mission of "Improving Human Living Conditions" and because we work by scientists for scientists, Eppendorf has a strong interest in sustainability. This is not limited to corporate improvements but focuses on the products in the laboratories worldwide.

We have come a big step closer towards our goal of reducing the CO2 emissions in our own operations (Scope 1 +2) to zero by 2028. Between 2019 and 2022, we were able to reduce our direct emissions by 58%. The switch to 100% renewable electricity contracts at almost all production sites was the key to this significant reduction. The next steps will be more challenging. In addition to our own internal target, we have signed up to the Science Based Target initiative (SBTi) in 2023. As SBTi also includes Scope 3 emissions, it covers a broader range of emissions. In the medium term, our internal target will merge with the SBTi targets.

THE FUTURE OF PLASTIC

Plastic consumables are used every day in laboratories all over the world. But as versatile and necessary, they also have a major impact as they are made from (limited) fossil fuels. And finally, it ends up in big bags of plastic waste. Both aspects need to be addressed.

Supporting a circular economy by using recycling plastic material is the midterm goal, but the plastic waste mountains are still waiting for a reliable approach: Traditional recycling technologies deliver you shortened polymer chains that are less stable when being used as tubes in the centrifuge. In addition, the recycling of plastic introduces leachable substances into the samples. Both impacts need to be solved before recycled material is a candidate for tubes, plates, and plates.

Since mid-2024, a growing number of Eppendorf tip racks have been made from 100% recycled plastic. This specific recycled material from a dedicated post-consumer source guarantees a constant flow of high-quality plastic. As there is no direct contact of recycled plastic with samples, the challenges mentioned can be neglected.

As an alternative approach, Eppendorf developed consumables made from biobased plastic in 2022. By using 2nd generation biobased material from waste streams such as agriculture waste, e.g. wheat straw, food waste, or waste oils, such as used cooking oil (UCO), this raw material is recycled for a second life in the laboratory. The entire process is monitored and certified by ISCC plus, an independent organization.

Following the market launch of the Eppendorf Tubes® BioBased, Eppendorf has successively expanded its portfolio of biobased consumables. Both the epT.I.P.S.® (with and without filter) and our Eppendorf twin.tec® PCR Plates are now available as biobased versions. We are very pleased that biobased consumables are being well received by more and more users. Further biobased products are in development.

PRODUCT CARBON FOOTPRINT

Science demands evidence – and so, carbon footprint analyses were carried out for our new biobased consumables. To this end, classic, fossil fuel-sourced consumables were compared with their biobased counterparts. These studies, which were conducted externally based on the cradle-to-the-gate approach, demonstrated considerable CO2 savings. E.g. the use of at least 90% biobased material in 5 mL conical tubes resulted in CO2 savings of 17.9%, equivalent to 3.3 g of CO2 per tube.

The results of the analysis of the 5 mL tubes served as a starting point for estimating the CO2 savings for our 15 mL, 25 mL, and 50 mL tubes. The change of raw materials alone results in carbon savings of 5.6 g CO2 for 15 mL tubes; of 6.7 g CO2 for 25 mL tubes; and of 11.1 g CO2 for 50 mL tubes. These results have also been published and further data on other products will follow.

BIOPLASTIC VERSUS BIODEGRADABILITY

Despite the success of biobased materials, there remains confusion about their biodegradability. In fact, most bioplastics are not compostable. The Eppendorf biobased consumables are made from biobased polypropylene (PP), or biobased polycarbonate (PC), respectively, which do not decompose.

The desire for biodegradability often leads to the risk of biohazards and residual reagents being ignored. This also represents a major challenge on the road to a circular economy. The medium-term goal consists of finding a way to close the material cycle as well as develop a reliable, reasonable, and safe recycling system for laboratory consumables. These goals will require time and effort from all of us. Supporting the concept of the circular economy is also the aim of the EU Packaging and Packaging Waste Regulation (PPWR) which entered into force beginning of 2025. This will force both industry and recycling firms to tackle packing waste from both directions, prepare for the circular economy, and create the infrastructure needed to recycle waste.

INDEPENDENT VERIFICATION

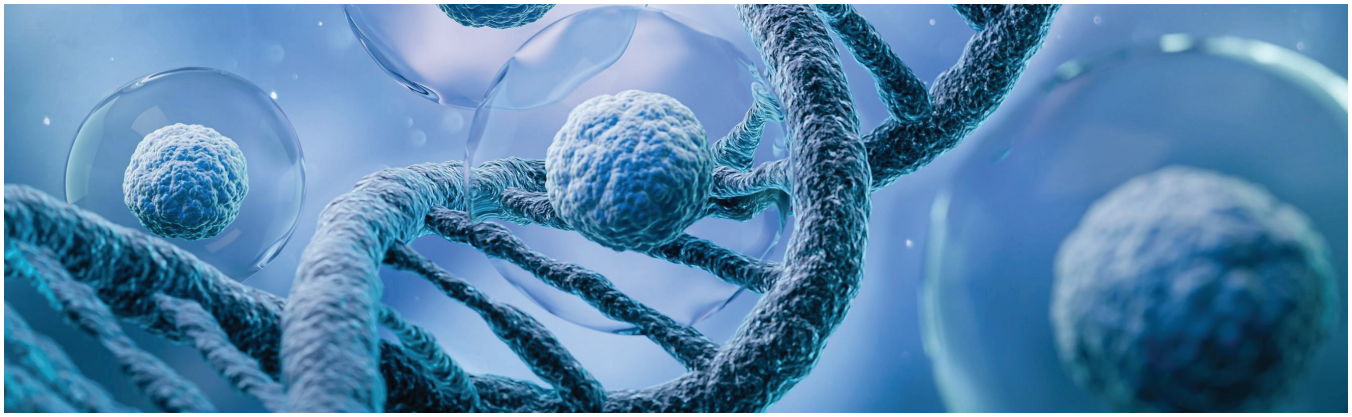
We see real added value for our customers in independent validation of the sustainability of our products through third parties. For this reason, we are further expanding our partnership with My Green Lab®, which we have had since 2017. In addition to freezers, centrifuges, and consumables, in the last months we also received the ACT label within new product categories as dispensing tools, mixers, and cyclers. We are also a member of the ACT 2.0 steering committee, which is developing the future of ACT.

CONCLUSION: THE JOURNEY CONTINUES

One central finding of our sustainability engagement is the fact that product carbon footprint analyses are complex, and that they demand much time, capacity and resources. At the same time, progress with respect to sustainability is never finished and complete. Rather, we find ourselves on a continuous, exhilarating journey. A long-term journey which also requires a constant discourse with our stakeholders. ■

SUSTAINABILITY IN CLEANROOM MANUFACTURING: THINKING OUTSIDE THE BOX

Submitted by Chelsea Lauridsen | Germfree



THE PRINCIPLES OF SUSTAINABILITY — REDUCE, REUSE, RECYCLE — HAVE LONG BEEN APPLIED ACROSS INDUSTRIES, BUT INTEGRATING THEM INTO CLEANROOM MANUFACTURING PRESENTS UNIQUE CHALLENGES. CLEANROOMS ARE ESSENTIAL FOR CRITICAL APPLICATIONS IN BIOTECHNOLOGY, PHARMACEUTICALS, AND RESEARCH, YET TRADITIONAL DESIGNS OFTEN LEAD TO SIGNIFICANT MATERIAL WASTE, HIGH ENERGY CONSUMPTION, AND LIMITED REUSE POTENTIAL. BY RETHINKING CONVENTIONAL APPROACHES, THE INDUSTRY CAN IMPROVE

One avenue for reducing waste in cleanroom manufacturing is modularity and mobility. Traditional cleanrooms are typically built as permanent structures, requiring demolition and reconstruction when needs change or facilities relocate. This process is resource-intensive, generating construction waste and increasing costs. Modular and mobile cleanrooms, however, provide a more sustainable alternative by allowing relocation and reuse, reducing the need for new materials and minimizing environmental impact.

Real-world examples demonstrate the effectiveness of this approach. Germfree has successfully relocated high-containment labs while maintaining full functionality. In Singapore, a Germfree-built ABSL-3 lab was moved after a decade of use, proving that cleanrooms can be repurposed rather than discarded. Similarly, a Germfree BSL-3 lab originally deployed by the Department of Health for the U.S. Virgin Islands was relocated after five years, extending its operational lifespan without unnecessary waste. Even in industrial applications, Germfree cleanrooms have been resold and repurposed, as seen in a Texas-based lab originally built for Chevron that later found a new home instead of being decommissioned.

BEYOND REUSABILITY, OPTIMIZING THE SUPPLY CHAIN AND MANUFACTURING PROCESS ALSO CONTRIBUTES TO SUSTAINABILITY. GERMFREE MANUFACTURES ITS CLEANROOMS IN A CONTROLLED ENVIRONMENT, ALLOWING FOR PRECISE MATERIAL USAGE AND REDUCING EXCESS WASTE. SOURCING MATERIALS IN BULK AND MINIMIZING TRANSPORTATION EMISSIONS FURTHER ENHANCES ENVIRONMENTAL RESPONSIBILITY. ADDITIONALLY, GERMFREE'S ENGINEERING DESIGNS PRIORITIZE EFFICIENCY—SUCH AS MODULAR COMPONENTS THAT CAN BE RECONFIGURED INSTEAD OF DISCARDED—HELPING EXTEND THE LIFE CYCLE OF CLEANROOM FACILITIES.

Sustainability in life sciences and cleanroom manufacturing extends beyond energy-efficient equipment or eco-friendly materials; it requires a fundamental shift in how facilities are designed, built, and repurposed. By embracing mobility, modularity, and responsible manufacturing, the industry can significantly reduce its environmental footprint while maintaining the highest standards of performance. As cleanroom technology continues to evolve, integrating sustainability from the ground up will be essential in shaping a more resource-efficient future. Every step we take today brings us closer to a greener, more efficient tomorrow! ■

AI-DRIVEN SUSTAINABILITY IN BIOMANUFACTURING: SHAPING THE FUTURE OF SMARTER, FASTER AND GREENER PRODUCTION

Submitted by Reza Farahani, CEO | Katalyze AI

THE SUSTAINABILITY CHALLENGE IN BIOMANUFACTURING

Biopharmaceutical manufacturing is resource-intensive. Precision is everything—temperature, pressure, and nutrient levels, all have to be perfectly calibrated. However, in contrast to small molecules, manufacturing biologics is often inefficient. Batch failures happen. Deviations occur, disrupting processes, increasing waste, and driving up energy consumption.

The industry faces a sustainability challenge, not due to a lack of commitment, but because existing systems were designed for consistency rather than optimization at scale. AI is shifting that. Instead of relying on static process control, AI-driven systems learn from every batch, adapting and refining production in real-time.

OPTIMIZING FERMENTATION THROUGH AI-DRIVEN PROCESS CONTROL

Take fermentation-based manufacturing. Biologics are made using living cells—yeast, bacteria, mammalian cells—each with their own quirks. A small shift in temperature, pH, dissolved oxygen, or raw material quality can throw off an entire batch, leading to wastage, costly shutdowns, and excess energy consumption. AI models predict these fluctuations before they happen, adjusting process conditions dynamically.

Biomanufacturers have relied on trial-and-error and static control strategies for decades. That's no longer enough. AI-driven fermentation control enables a data-first approach that continuously learns from every production cycle, optimizing conditions in real-time. This means:

- **Lower batch failure rates.**
  AI-driven deviation detection and root cause analysis can reduce batch failures by up to 30%, cutting material and energy waste while improving production yield.

- **Smarter energy consumption.**
  AI optimizes aeration, agitation speeds, and cooling cycles, reducing unnecessary energy use— and saving up to 25% on energy costs in large-scale fermentation systems.

- **Adaptive nutrient feeding.**
  AI dynamically adjusts glucose, amino acids, and other critical feedstocks based on real-time cell metabolism, preventing overfeeding, reducing excess biomass, and improving final product consistency.

- **Advanced metabolic modeling.**
  AI integrates real-time process data with metabolic models to optimize conditions for microbial or mammalian cell growth, ensuring higher product titer while minimizing resource use.

- **Precision pH and oxygen control.**
  Traditional bioprocess monitoring often reacts after deviations occur. AI-driven controls anticipate and correct deviations before they impact product quality, reducing rework and scrap.

- **Optimized batch-to-batch reproducibility.**
  AI learns from previous runs to refine conditions, eliminating variability across different production sites and suppliers.

- **Reducing fermentation time.**
  By predicting optimal process parameters, AI can reduce fermentation cycle times, increasing throughput without requiring additional infrastructure investment.

- **Minimizing contamination risks.**
  AI-driven anomaly detection catches deviations within minutes, reducing contamination risks that could otherwise lead to batch discards.

REDUCING CARBON FOOTPRINT THROUGH AI-POWERED OPTIMIZATION

A global biologics company like Sanofi produced more than 164,000 tons of waste in 2023, at least 20,000 tons of which cannot be recycled, reused or recovered. Waste incineration produces approximately 0.7-1.7 metric tons of CO2 per ton of waste.

Katalyze AI's expertise lies in turning fermentation from guesswork into data-driven optimization. Every variable in bioprocessing—temperature, pH, nutrient flow, gas exchange—can be continuously adjusted based on real-time AI-driven insights, delivering more predictable, scalable, and sustainable biomanufacturing.

AI-Driven Sustainability in Biomanufacturing: Shaping the Future of Smarter, Faster and Greener Production Optimizing fermentation process controls not only increases yield but also significantly reduces the carbon footprint of biomanufacturers. Katalyze AI's platform addresses this by:

Predicting and Preventing Deviations

Traditional manufacturing approaches rely on historical data analysis and manual process adjustments. AI enables real-time monitoring and predictive insights, reducing the risk of failed batches and cutting unnecessary energy and material waste.

Optimizing Raw Material Use

Biopharma production depends on high-quality raw materials, yet variability in sourcing often leads to inefficient batch processing. AI models identify optimal input conditions, ensuring consistent output while minimizing excess resource use.

Enhancing Process Efficiency

AI-enabled process control continuously refines biomanufacturing parameters—such as temperature, agitation, and nutrient feeding—leading to a more energy-efficient and reliable production process.

THE FUTURE OF AI-ENABLED SUSTAINABILITY IN LIFE SCIENCES

The future of sustainable biomanufacturing hinges on data-driven decision-making. AI has already unlocked unprecedented efficiencies in process development, but its potential in sustainability remains largely untapped. As more life sciences organizations prioritize ESG initiatives, AI will play a critical role in making sustainable manufacturing not only possible but profitable.

Sustainability in life sciences isn't just about compliance—it's about building a future where efficiency and environmental responsibility go hand in hand. ■

PLASTIC WASTE GENERATION

Submitted by Labcon

PLASTIC WASTE GENERATION IS A SIGNIFICANT ISSUE IN THE LAB SPACE. THE IMPACT OF SINGLE-USE PLASTICS MANUFACTURING HAS TREMENDOUS, MULTI-FACETED, ADVERSE EFFECTS ON THE ENVIRONMENT. COMPREHENSIVE APPROACHES TO ADDRESSING AND MONITORING THESE IMPLICATIONS CAN HELP MITIGATE THESE IMPACTS. THE SUPPLY CHAIN, NOTED AS SCOPE 3 EMISSIONS, HAS ALSO BEEN IDENTIFIED AS A MAJOR CONTRIBUTOR TO CLIMATE CHANGE AND RESOURCE DEPLETION. THIS UNDERSCORES THE NEED FOR EXTENDED PRODUCER RESPONSIBILITY ACROSS A PRODUCT'S LIFE CYCLE TO FOSTER MORE SUSTAINABLE PROCUREMENT PRACTICES.

The manufacturing industry is undergoing a green transformation. Increasing demand for more environmentally responsible manufacturing practices is steadily transforming the industry. Sustainable manufacturing, as a resource-intensive operation, often analyzes key metrics of energy, waste, water, and emissions. Labcon has pioneered this responsibility as The Earth Friendly Company for over 30 years by continuously monitoring and adopting initiatives that limit its net environmental footprint.

A philosophy of being earth-friendly and continuously improving has led to significant enhancements in our key sustainability performance metrics since 2000. By conducting

holistic life cycle assessments from sourcing to end-of-life, we minimize our environmental impact through eco-centric products, processes, and partnerships. This has driven strategic reductions in logistics and distribution, responsible sourcing of materials, and packaging waste reduction, all while considering circular economy principles. Transparency and traceability efforts help combat greenwashing by establishing clear criteria. The ACT® Label has been pivotal in substantiating claims by quantifying products' eco-impact with an independent auditor. Labcon's commitment is embodied by having over 250 ACT®-labeled products with industry leading scores in manufacturing and emissions reductions.

Promoting a reduce, reuse, and recycle mindset throughout the product life cycle is essential for enabling sustainable decisions downstream. Sustainable supply chains start with thoughtful sourcing and design practices. By ensuring that 90% of all raw and packaging materials are locally sourced within 100 miles of our manufacturing and distribution warehouses, the environmental impact is minimized. The remaining 10% of materials are obtained from other regions within the United States. Accountable decision-making can avoid unnecessary waste and resource use.

Addressing the plastic waste problem begins with optimizing resource utilization and using only necessary packaging components to maintain product integrity. Partnering with suppliers who use eco-friendly materials over nonrenewable ones is critical. The incorporation of recyclable bioplastic resins in product components aids in the removal of CO2 from the atmosphere. Additionally, using recyclable materials with clear recycling codes and providing recycling guides assures sustainable end-of-life disposal alternatives, diverting landfill waste where infrastructure allows. Fiber-based, renewable packaging components, certified by the Forest Stewardship Council (FSC) and containing pre-recycled content, further enhance these efforts.

EMISSIONS AND EFFICIENCY

Imagine revolutionizing production and logistics systems to curb emissions and boost efficiency. Over the last 25 years, production and product handling strategies have significantly reduced emissions in logistics and distribution. Efficient logistics and operations minimize our direct impact. By consolidating all manufacturing processes - molding, assembly, packaging, sterilization, and shipping - within a half-mile radius in Petaluma, lead times, emissions, and transportation energy have been drastically reduced. These initiatives have cut 55 metric tons of CO2 annually and shortened product lead times by at least a week. Additionally, our e-beam sterilization method is free of radioactive waste.

Innovative resource management also extends to water efficiency within our operations by achieving an 81% reduction per case made. By implementing a closed-loop water cooling system, water usage was cut by approximately two-thirds. Replacing the previous water-cooling tower has led to near-zero water loss. Other efforts related to our landscaping and facility infrastructure have contributed to this reduction.

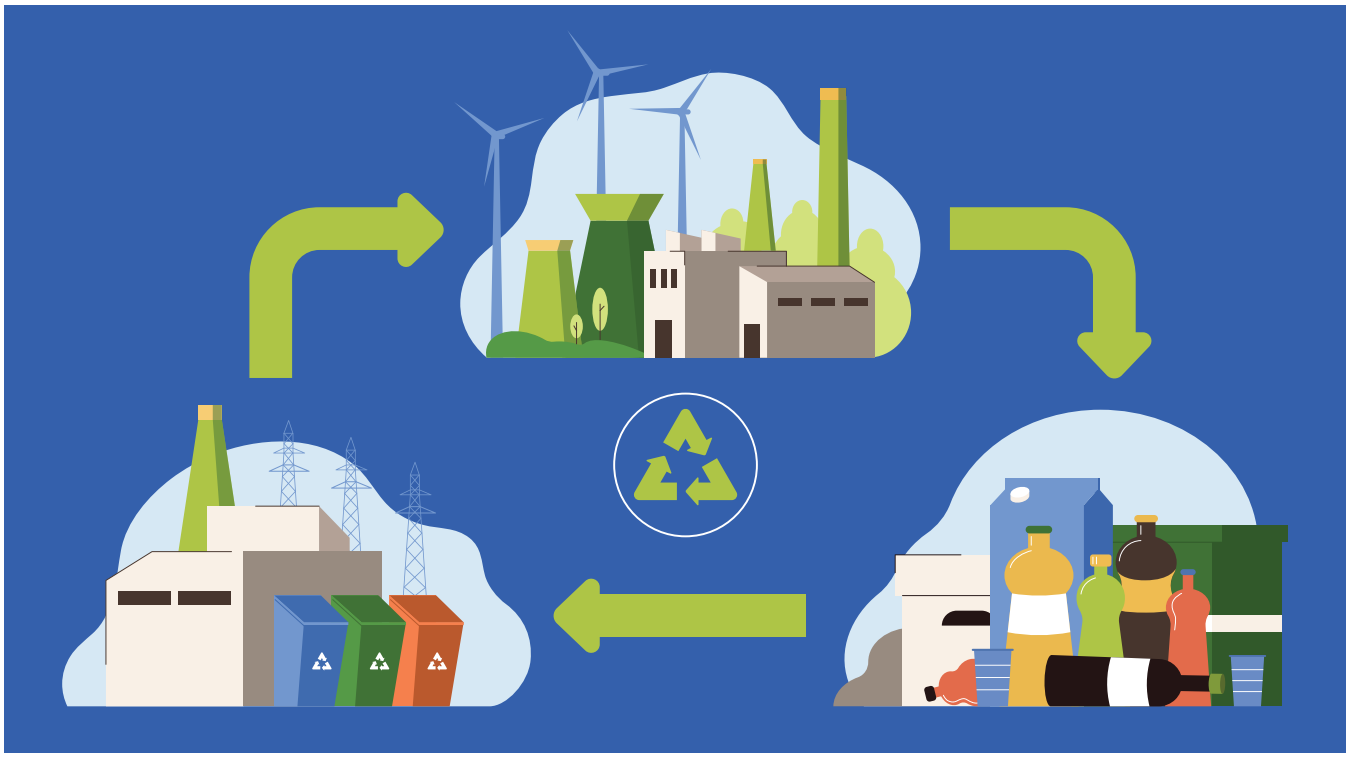
ENERGY-EFFICIENT TECHNOLOGIES AND PRACTICES

Environmental stewardship extends to significant efforts to reduce greenhouse gas emissions, a key focus in environmental impact discussions. Our annual greenhouse gas emissions have been reduced by 89% per case of manufactured product. This achievement aligns with our increased use of clean energy, decreasing reliance on fossil fuels and improving energy efficiency. More efficient manufacturing processes have further reduced energy consumption and associated emissions. By investing in energy-efficient technologies and practices, we have lowered energy consumption by 60% per case. Our products are made with 93% clean energy, generated from onsite solar and partnerships with a nonprofit green energy provider. This clean energy includes solar (purchased and onsite), hydroelectric, wind, geothermal, and renewable other sources.

EFFECTIVE RECYCLING

Partnering with Polycarbin, we close the loop on lab plastic waste, reducing the need for new raw materials. This collaboration ensures effective recycling and repurposing of lab items, addressing the challenge of non-recycled materials. By designing reusable products with higher quality materials, we promote product reuse as the most sustainable solution. The Eclipse™ pipette tip refill system, with reusable racks and reduced packaging, exemplifies these attributes. Components are made from post-industrial recycled plastic to maximize resource utilization. Our waste reduction efforts have cut waste by 86% per case, including packaging. Plastic scrap from tip and tube production is reprocessed into molded racks and accessory components, with most made from 100% pre-consumer recycled plastic from our in-house recycling program. Emphasizing full use of resins and switching to hot runner molds has significantly aided these efforts.

By embracing a holistic approach to sustainability and collaborating with stakeholders across the supply chain, we are making more sustainable decisions and building a greener future for science. Integrating circular economy principles and adopting a cradle-to-cradle mindset, we optimize resource utilization and reduce our environmental footprint. Fostering a greener, more responsible industry is our prerogative. Our commitment to sustainable manufacturing, efficient logistics, and eco-friendly product design demonstrates our dedication to creating a positive impact and advancing sustainability in the community.



THE BUSINESS CASE FOR SUSTAINABILITY IN CELL THERAPY DEVELOPMENT: INNOVATIONS AND STRATEGIES

Submitted by Nucleus Biologics

THE LIFE SCIENCES INDUSTRY IS AT THE FOREFRONT OF SCIENTIFIC INNOVATION BUT ALSO CARRIES A SIGNIFICANT ENVIRONMENTAL FOOTPRINT. FROM ENERGY-INTENSIVE RESEARCH FACILITIES TO SINGLE-USE PLASTICS, THE SECTOR FACES SUSTAINABILITY CHALLENGES. AS GLOBAL EFFORTS TO COMBAT CLIMATE CHANGE ACCELERATE, LIFE SCIENCES COMPANIES—PARTICULARLY THOSE IN CELL THERAPY—MUST INTEGRATE SUSTAINABILITY INTO THEIR OPERATIONAL STRATEGIES. ORGANIZATIONS THAT PRIORITIZE SUSTAINABLE PRACTICES MITIGATE RISK WHILE GAINING COMPETITIVE ADVANTAGES THROUGH COST SAVINGS, OPERATIONAL EFFICIENCIES, AND ENHANCED BRAND REPUTATION.

SUSTAINABILITY AS A DRIVER OF BUSINESS VALUE

Sustainability in life sciences extends beyond environmental responsibility; it is a business imperative that intersects with health equity, cost efficiency, and regulatory compliance. Climate change disproportionately impacts vulnerable populations, exacerbating health disparities. Companies that reduce waste, optimize supply chains, and invest in renewable energy lower costs while ensuring broader access to medical advancements.

At Nucleus Biologics, we integrate sustainable practices to minimize our environmental footprint while enhancing efficiency. We have specifically designed our ISO 13485-certified cleanrooms to reduce waste and energy consumption, and we prioritize suppliers that incorporate sustainable practices and waste management programs with recycling initiatives.

By consolidating shipments, using recyclable packaging, and leveraging reusable shipping containers, we lower transportation emissions. We also incorporate ozone sanitization in our WFI water system, purchase second-hand equipment, and optimize manufacturing resources.

A growing component of our sustainability efforts is Krakatoa, our benchtop media maker enabling on-site cell culture media production. By integrating Krakatoa for small-lot media manufacturing, we reduce reliance on traditional liquid media packaging and refrigerated storage, cutting plastic waste and energy use. Krakatoa pods, made from compostable and recyclable materials, further reinforce our commitment to sustainable packaging

KEY STRATEGIES FOR SUSTAINABLE CELL THERAPY MANUFACTURING

Biotech companies can implement the following sustainability initiatives:

1. GREEN LABORATORY PRACTICES

Laboratories consume up to ten times more energy per square foot than office buildings. Companies can reduce costs and environmental impact by investing in energy-efficient freezers, implementing water-saving protocols, and adopting digital documentation. Programs such as My Green Lab provide certification pathways for sustainable options.

2. SUSTAINABLE MANUFACTURING AND SUPPLY CHAINS

Adopting green chemistry reduces hazardous waste and reliance on nonrenewable resources, lowering regulatory risks and disposal costs. Companies should prioritize solvent recovery, biodegradable packaging—such as Krakatoa pods—and sustainable sourcing of reagents.

Krakatoa enhances sustainability by enabling cell culture media production at the point of use, reducing reliance on traditional supply chains and minimizing packaging waste. Decentralized manufacturing hubs and lighter packaging can further decrease environmental impact while improving supply chain efficiency.

3. REDUCING SINGLE-USE PLASTICS

Single-use plastics are essential in cell therapy manufacturing due to sterility requirements, but innovative solutions can mitigate their impact. Companies should invest in biodegradable or reusable lab plastics, encourage suppliers to use sustainable packaging, and participate in take-back programs for plastic waste.

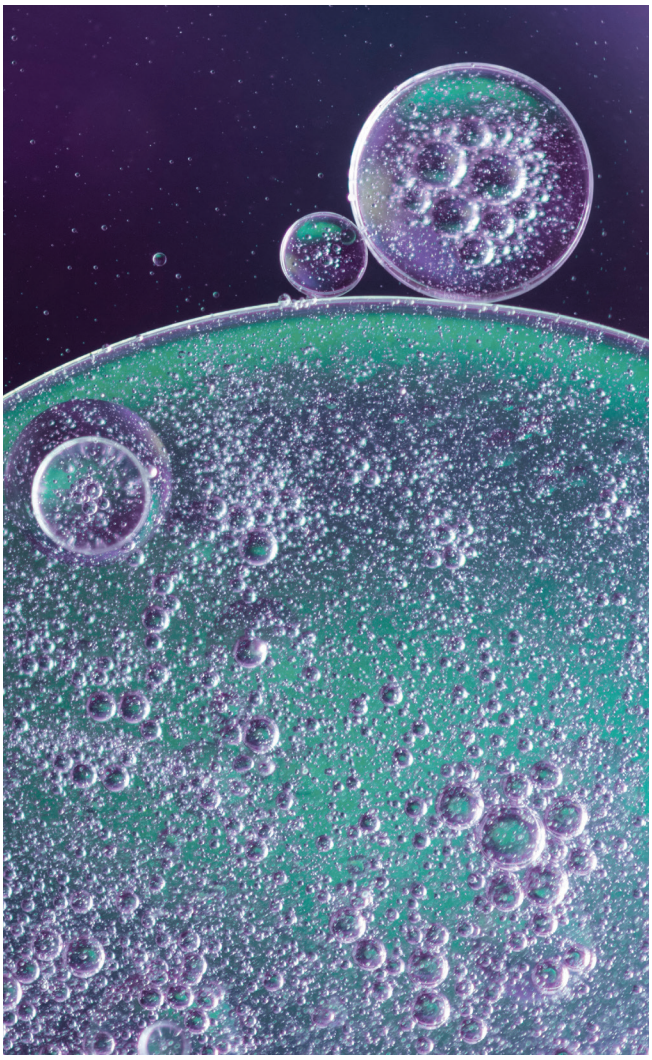
Nucleus Biologics' Krakatoa addresses this challenge by utilizing compostable, recyclable, and biodegradable pods, significantly reducing plastic waste compared to traditional liquid media containers.

4. RENEWABLE ENERGY ADOPTION

Transitioning to renewable energy sources such as solar and wind power can drastically reduce carbon emissions in research and manufacturing facilities. Many biotech companies are committing to net-zero emissions by integrating renewable energy and leveraging carbon offset programs, reducing environmental impact while shielding companies from fluctuating energy costs.

5. SUSTAINABLE PROCUREMENT STRATEGIES

A company's environmental footprint extends beyond its facilities to its supply chain. Vetting suppliers for sustainability practices, prioritizing vendors with environmentally friendly certifications, and consolidating shipments to reduce transportation emissions can lower costs while reducing carbon footprint.



OVERCOMING BARRIERS TO SUSTAINABILITY IN CELL THERAPY

While the advantages of sustainability are clear, several challenges must be addressed:

1. MANAGING COSTS AND ROI UNCERTAINTY

A common concern is the perceived high cost of sustainable initiatives. While energy-efficient equipment and green chemistry alternatives require upfront investment, long-term savings from reduced waste, lower energy expenditures, and improved efficiency often offset these costs. Companies can leverage government incentives, grants, and industry partnerships to mitigate financial risks.

2. REGULATORY AND COMPLIANCE CONSIDERATIONS

Stricter regulatory requirements can complicate sustainability efforts. For example, transitioning to biodegradable packaging may require new validation and compliance processes. Engaging with regulatory bodies early and collaborating with industry groups can help companies navigate these complexities and create standardized sustainability guidelines that align with compliance needs.

3. CULTURAL RESISTANCE TO CHANGE

Implementing sustainable practices often requires a cultural shift. Employees may resist changes to long-established protocols. Education initiatives, incentive programs, and strong leadership commitment are essential to fostering widespread adoption of sustainable practices.

4. LIMITED INFRASTRUCTURE FOR RECYCLING AND WASTE MANAGEMENT

Many laboratories lack access to recycling programs for specialized waste streams, such as used pipette tips and cell culture plastics. Partnering with waste management providers specializing in biotech recycling and advocating for industry-wide recycling initiatives can help address this gap and improve sustainability.

THE PATH FORWARD: SUSTAINABILITY AS A COMPETITIVE ADVANTAGE

Sustainability in cell therapy development is not just an ethical responsibility—it is a strategic advantage. As the industry evolves, companies that integrate sustainable practices will drive innovation, reduce costs, and strengthen competitive positioning. By adopting green laboratory practices, optimizing supply chains, reducing single-use plastics, and leveraging renewable energy, biotech organizations can minimize their environmental footprint while maintaining the highest standards of quality and compliance.

At Nucleus Biologics, we recognize that sustainability and scientific advancement go hand in hand. Through advancements like Krakatoa, we are reshaping how cell culture media is produced—minimizing waste, reducing transportation emissions, and utilizing biodegradable packaging to create a more responsible supply chain. Our commitment to sustainable manufacturing and waste reduction underscores our dedication to building a future where cell and gene therapy innovation is both cutting-edge and environmentally conscious.

As climate change and resource conservation challenges intensify, the life sciences industry must rise to the occasion. By prioritizing sustainability today, we ensure that the groundbreaking therapies of tomorrow are developed with efficiency, responsibility, and longevity in mind. ■

BEYOND STEEL: BUILDING A SUSTAINABLE FUTURE FOR BIOLOGICS PRODUCTION

Submitted by Emmanuel Klein | Plantibodies

THE GROWING MARKET FOR GLP-1 AND BIOLOGICS

Regulatory agencies such as the FDA and EMA have approved GLP-1 receptor agonists for the treatment of obesity and diabetes, with leading pharmaceutical companies like Novo Nordisk and Eli Lilly at the forefront. Other firms, while currently lagging, are rapidly entering this high-growth sector.

The GLP-1 market is projected to reach $46.7 billion in 2024, and an unprecedented $322.85 billion by 2034, with a compound annual growth rate (CAGR) of 18-21.3%. If these projections materialize, GLP-1 therapeutics could surpass the iPhone in annual revenue, marking a historic milestone where a biologically manufactured molecule becomes the best-selling pharmaceutical product worldwide.

Beyond diabetes and metabolic disorders, GLP-1 agonists are increasingly being utilized for cosmetic weight loss, driven by consumer trends, influencer endorsements, and off-label demand, further accelerating market growth.

MANUFACTURING CONSTRAINTS: THE SCALABILITY CHALLENGE

Despite surging demand, GLP-1 production methods remain largely unchanged since Genentech's 1980s biomanufacturing process. Although the pharma acknowledges its role in contributing to global greenhouse gas (GHG) emissions and is proactively setting its own objectives to align with the Paris Agreement's goals.

However, the current manufacturing methods still rely on:

- Genetically engineered cells cultivated in stainless-steel bioreactors
- Multi-step purification, chemical modification, and formulation
- Production of injectables or tablets for systemic administration

Scaling this process to meet future demand presents significant industrial and environmental challenges.

By 2025, global GLP-1 production must reach 70 metric tons of API per year, increasing to 160 metric tons by 2030—a dramatic expansion that will intensify biomanufacturing emissions. And this is just for GLP-1. Imagine for the entire biologics market!

Despite ongoing efforts, it is evident that the pharmaceutical industry is struggling to align with environmental sustainability goals.

Could there be a different approach to achieving these goals more effectively?

REEVALUATING BIOLOGICS MANUFACTURING: A SHIFT TOWARD MOLECULAR FARMING

In the 1980s, scientists explored using plants as bioreactors to produce biologics, capitalizing on low-cost biomass and scalable production. A 1990 study in Nature Biotechnology suggested that plants could serve as viable microbial expression systems due to cost-effective biomass production.

However, the 2002 Prodigene contamination incident resulted in regulatory barriers and industry skepticism, leading pharmaceutical companies to favor predictable, steel-tank fermentation over plant-based alternatives.

Given the current challenges in biologic manufacturing, should the industry reconsider transitioning—at least partially—away from cell-based biomanufacturing?

As Stanford bioengineering professor Drew Endy aptly states: "Leaves on a tree don't come from a factory and get shipped and taped to branches—the photons and molecules arrive, and the biology grows locally."

Currently, biologics are exclusively injected and depend on systemic distribution to reach target tissues. While effective, this method necessitates high and frequent dosages, resulting in significant side effects and imposing economic burdens on healthcare systems, patients, and families.

Could a shift in production methods or alternative delivery mechanisms reduce the overall demand for biologics, thereby lowering their carbon footprint, especially when the oral biologics market is forecasted to exhibit a CAGR of 35,4% (2024-2030)?

TARGETING THE GUT: A NEW PARADIGM FOR A RISING DEMAND IN GI TARGETED

Currently, 5–7% of approved biologics (approximately 20–30 drugs) are indicated for gastrointestinal (GI) diseases, generating $20 billion annually. This includes treatments for:

- Inflammatory Bowel Disease (IBD): Crohn's disease, ulcerative colitis
- GI cancers
- Rare gut-related disorders

The rise of precision medicine and microbiome-targeted therapies suggests this market share will increase in the coming decade. Notably, 10–15% of late-stage biologics drug candidates in 2023 targeted
GI diseases, highlighting the industry's growing interest in gut-targeted biologics.

A NOVEL MODEL FOR SUSTAINABLE ORAL BIOLOGICS DRUG PRODUCTION

Imagine if monoclonal antibodies (mAbs) designed to treat GI conditions could be produced in plants rather than in conventional steel bioreactors. With molecular farming, plants grown in carbon-neutral vertical farms could serve as living biofactories. In this model:

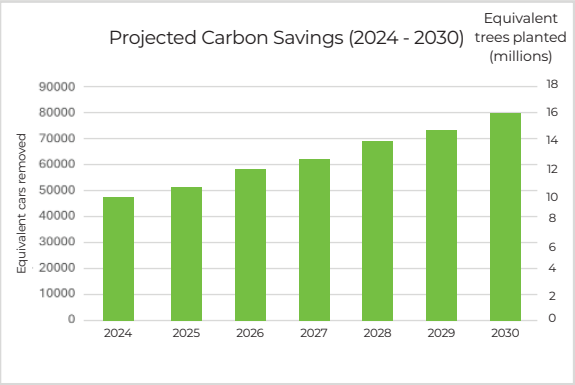
- Biologics are produced within plant cells, which inherently protect the active ingredients.
- The harvested plant material is dried, lyophilized, and encapsulated — bypassing energy-intensive purification steps.
- The encapsulated product, when administered orally, delivers the drug directly to the colon, potentially reducing systemic side effects and improving patient compliance.

ENVIRONMENTAL AND ECONOMIC BENEFITS OF PLANT PRODUCED COLON-TARGETED ORAL BIOLOGICS

This innovative approach could transform biologics manufacturing by:

- Eliminating energy-heavy purification and cold-chain storage significantly lowers emissions.
- Enhancing patient accessibility: Oral administration improves compliance and reduces the economic and logistical burdens associated with IV infusions.
- Lowering production costs: The streamlined process cuts down on expensive fermentation and purification steps.
- Scalability: Plant-based systems offer a more flexible and sustainable platform for mass-market biologics production.

AND THE IMPACT SHALL BE IN THE FOLLOWING EQUIVALENTS:



As the demand for biologics rises, plant-based monoclonal antibodies (mAbs)—produced without purification—present a scalable, cost-effective, and sustainable alternative to address the industry's ongoing challenges.

PLANTIBODIES: A BUSINESS CASE FOR ORAL BIOLOGICS / A SCIENTIFIC BREAKTHROUGH IN BIOLOGICS DRUG DELIVERY

As the demand for biologics continues to skyrocket, the industry faces a critical juncture. Traditional methods—rooted in decades-old technologies—may no longer suffice in a world increasingly focused on sustainability.

One of the greatest limitations in oral biologics drug development has been ensuring stability through the digestive tract while effectively delivering the drug to the site of the disease. This challenge has been overcome through the encapsulation of monoclonal antibodies within plant cells. This natural protective barrier preserves biologics integrity through digestion, allowing the drug to reach the colon intact and release its therapeutic payload precisely where needed.

Embracing plant-based molecular farming for the production of oral, GI-targeted biologics could not only meet the surging demand but also help the pharmaceutical sector achieve its environmental goals under the Paris Agreement. This paradigm shift represents not just an industrial innovation but a necessary evolution toward a more sustainable future.

BIOMANUFACTURING AND THE FUTURE OF CHOCOLATE: A SUSTAINABLE SOLUTION TO COCOA'S CHALLENGES

Submitted by Yali Biosciences

BIOMANUFACTURING AND THE FUTURE OF SUSTAINABLE COCOA

Biomanufacturing, the use of biological systems such as microbes or cells for the commercial production of biomolecules, has long played a vital role in food production. Scalable, fermentation-derived products—including yeast for baking and brewing, microbial chymosin for cheese-making, and other enzymes for food processing—have revolutionized the food industry. However, the potential of biomanufacturing extends far beyond these applications. As climate change, soil degradation, and disease increasingly threaten traditional agriculture, there is a growing need for alternative, sustainable supplies of fundamental food ingredients such as proteins and fats.

One of the most pressing examples of this challenge is the cocoa industry, which is currently experiencing major disruptions due to environmental and disease-related challenges. In recent years, El Niño weather patterns have severely affected cocoa crops in West Africa, leading to a significant decline in yields. Cocoa production is highly dependent on tropical climates near the equator, with approximately 70% of the global supply coming from West Africa and another 20% from South America. As a result of this environmental crisis, cocoa prices reached an all-time high of $12,600 per ton in December 2024—a staggering 192% increase from December 2023. While weather conditions may eventually normalize, cocoa trees take years to mature, and climate change-driven extreme weather events are becoming more frequent. This means a full recovery of the cocoa industry, if possible, could take years. Climate change is amplifying disease risks, already responsible for over 30% of annual cocoa losses. Rising temperatures and unpredictable weather weaken plant resilience, further threatening cocoa-growing regions and increasing the urgency for sustainable alternatives.

BIOMANUFACTURING AS A SOLUTION

With demand for chocolate continuing to rise and conventional cocoa production becoming increasingly unsustainable, biomanufacturing offers a promising alternative. A number of startups are already developing bio-based solutions to address the cocoa crisis, and chocolate manufacturers—facing pressure on their supply chains—are beginning to take notice. In February 2025, Meiji, Japan's largest chocolate manufacturer, announced a commercial partnership with California Cultured, a California-based company using plant cell culture to produce cocoa powder. That same month, Swiss chocolate manufacturer Lindt & Sprüngli backed Food Brewer, a Zurich-based company with a similar technology. These companies are culturing cocoa cells in bioreactors to recreate the precise flavor compounds found in traditional cocoa, allowing for the production of bio-identical chocolate flavors.

While replicating cocoa powder is a crucial first step, a complete chocolate alternative requires more. Cocoa butter, a key ingredient in chocolate production, plays a crucial role in determining texture, melting properties, and overall sensory experience. Cocoa butter can account for up to 50% of a chocolate product's ingredients, making it an essential component of any alternative chocolate solution.

PRECISION FERMENTATION FOR SUSTAINABLE COCOA BUTTER

To address the growing challenges in cocoa production, Yali Bio is using yeast precision fermentation, a biomanufacturing approach, to develop a fat that functions just like cocoa butter while utilizing renewable sugar feedstocks. Unlike traditional cocoa butter, which relies on climate-sensitive tropical supply chains and contributes to deforestation, this method enables a stable, location-independent production using simple and renewable inputs. By integrating into existing biomanufacturing and oil-processing infrastructure, this approach offers a scalable and sustainable alternative.

Precision fermentation enables the engineering of fats that more closely replicate cocoa butter's composition and functionality than most existing alternatives. Conventional substitutes like palm oil and shea butter require extensive processing—fractionation and blending—to approximate cocoa butter's properties. With precision fermentation, microbes can be tailored to naturally produce fats that mimic cocoa butter's structure, melting behavior, and texture without additional refinement. Beyond replication, Yali Bio can fine-tune fat profiles to meet specific market needs, creating fats with optimized structure, texture, melting properties, and stability. This adaptability eliminates the need for complex fractionation and blending required by traditional plant-based alternatives, offering a more efficient and precise solution for the food industry.

As climate change continues to disrupt global agriculture, innovation in biomanufacturing is essential to creating more resilient food supply chains. Precision fermentation enhances the sustainability of cocoa butter supply chains by significantly reducing land use, cutting carbon emissions through localized production and shorter supply chains, and utilizing renewable resources. By reducing dependence on environmentally vulnerable crops, biomanufacturing not only stabilizes food production but also paves the way for a more sustainable and resilient global food system. ■

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