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Driving Environmental Sustainability in the Biopharmaceutical Industry

BioProcess International

Driving Environmental Sustainability in the Biopharmaceutical Industry

A Roundtable Discussion

Magali Barbaroux, Matteo Alaria, Katharina Tillmanns, Valeska Haux, Nate Verhanovitz, Daniel Fulford, Moritz von Wysiecki, and Miriam Monge

The benefits of single-use (SU) solutions are broadly known in the biopharmaceutical industry. During the COVID-19 pandemic, companies benefited from rapid implementation of SU manufacturing technologies, accelerating the production of life-saving drugs.

SU biomanufacturing processes enable significant sustainability improvements despite negative associations between SU plastics and environmental responsibility. Improvements are due primarily to reduced water use because cleaning procedures are not required. SU technologies also are flexible, enabling processes to be purpose-built to maximize facility efficiency. Additionally, closed and compact systems enable a smaller cleanroom footprint; by contrast, a traditional heating, ventilation, and air conditioning (HVAC) system is the single biggest energy consumer in a biomanufacturing facility (**1**).

In a recent panel discussion, sustainability experts from Sartorius and their external collaboration partners shared how manufacturers make their own processes more sustainable by adopting SU technologies, improving process efficiency, and forging productive collaborations (**2**). Here, we share extracts from those discussions and excerpts from Sartorius's white paper on sustainability in the biopharmaceutical industry (you can download the white paper using the code at the right).

The panelists, along with their titles and affiliations, are pictured on the following pages.

Flexsafe SU bags for storage and shipping

Download the white paper, "Driving Environmental Sustainability in the Biopharmaceutical Industry"

Defining Priorities

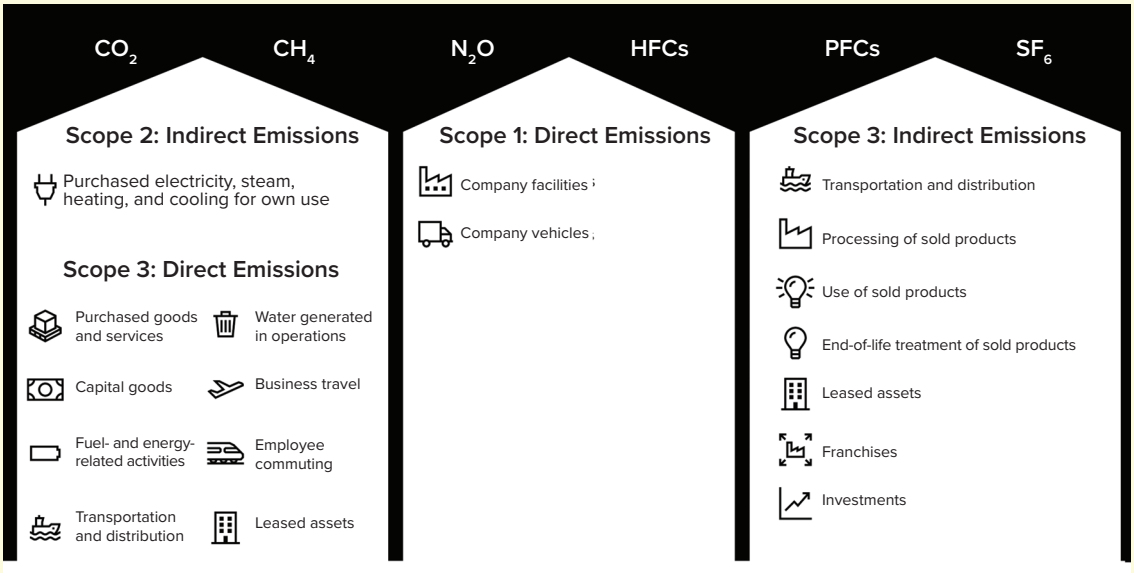
Moderator Miriam Monge began the panel discussion by asking important fundamental questions about selecting priorities when adopting sustainability initiatives.

Monge: *Do you see certain trends across industry suppliers regarding which sustainability initiatives they prioritize?*

Haux: The one main goal is to reduce CO_2 emissions. The good thing is that companies are not only concentrating on Scopes 1 and 2 (Figure 1) which are quite easy to achieve, but everybody's also looking at Scope 3, which enlarges the value chain.

We see two ways to reduce CO_2. The first possibility is to reduce material intensity while retaining needed performance from that material. The other is to implement a design for circularity,

Figure 1: Greenhouse-gas emissions



Scope 1 accounts for a company's direct emissions from energy combustion as well as from fugitive emissions. **Scope 2** accounts for a company's indirect emissions from energy purchased for electricity, heating, cooling, and steam. **Scope 3** accounts for a company's further indirect emissions in the upstream and downstream value chain, e.g., for purchasing products sold, logistics, and travel. The categorization of emissions is complex; they are not the result of activities owned or controlled by an organization but by activities up and down its value chain.

which will help to keep the materials in the loop and reduce the CO_2 footprint. [In closed-loop processes, material waste created during a production process is reused for additional products, and recycled products are used to create new items.] We at Südpack see the same trend in the food packaging industry.

von Wysiecki: Across the entire value chain, we see ambitious goals from all stakeholders. We see more and more collaborations popping up — parties are getting closer and working together to bring down CO_2 emissions and equivalents. And as previously mentioned, such activities are not valid only for Scopes 1 and 2, but are also relevant for Scope 3. Our organization, va-Q-tec, already is carbon neutral, so our ambition is to be a role model for sustainability strategies in the industry. Therefore, we offer our clients product carbon footprints that can measure and evaluate the entire life cycle of a product, including its supply chain.

Monge: *There are many different approaches to developing a sustainability program. How do you decide your priorities?*

Tillmanns: Our first step is to understand where our operations have an adverse impact on the environment and human rights. The second step is to evaluate whether those impacts are material and whether they constitute a risk or provide an

Moderator Miriam Monge, head of marketing, fluid management technologies, Sartorius (LEFT) and Valeska Haux, VP strategic marketing, Südpack (RIGHT)

Moritz von Wysiecki, global head of marketing, va-Q-tec AG (LEFT), and Katharina Tillmanns, head of corporate sustainability, Sartorius (RIGHT)

Südpack and Sartorius

Our partnership with Sartorius started more than 10 years ago and is highly motivated by sustainability. The Flexsafe film we are producing for Sartorius can be recycled and taken back into the material loop and is, therefore, an important milestone on the journey to circularity.

Valeska Haux, VP strategic marketing, Südpack

opportunity. In this process, we always include our stakeholders (e.g., our customers and suppliers). They account for many of the environmental impacts that we are seeing.

Based on that, we are developing our sustainability focus areas with targets on a corporate level, a defined mitigation path, and harmonized approaches. Our focus areas at the moment are climate action, materials and circularity, and water and effluents.

There obviously is no one-size-fits-all approach with sustainability programs. It depends on the business and where its impact hotspots are.

Monge: *We are obviously quite impressed with the goal of reaching the emission targets in Scopes 1 and 2 by 2030. How will Sartorius meet those goals?*

Tillmanns: One important thing to mention is that most emissions are found in the value chain (Scope 3). Only about 10% of our overall emissions are in Scopes 1 and 2. We have set ourselves the target to reduce emission intensity across all scopes by an average of 10% per year.

Some emissions are unavoidable, such as those associated with membrane production. For Scopes 1 and 2, we want to achieve zero avoidable emissions. Our first step is to improve the energy efficiency of all operational processes. The second step is to produce renewable energy on-site — for example, by installing solar panels where appropriate. The third step is to procure renewable energy by transitioning to electrification or renewable fuels. The last step is to address removal of unavoidable carbon emissions.

Matteo Alaria, head of product sustainability, Sartorius (LEFT) and Magali Barbaroux, research fellow, corporate research, Sartorius (RIGHT)

Overcoming Industry Challenges

Monge: *How important are collaboration, partnership, and the value chain across the industry to foster sustainability?*

Alaria: I think this is an area that requires a precompetitive approach to sustainability. Actors all along the chain need to come together to drive real change. When we collaborate openly with our partners, we want to identify areas of common interest and ways to improve efficiency. We can achieve bigger results if we're working together. Sartorius is working with a number of sustainability panels and groups in the industry. We're providing our inputs and trying to drive the discussion to come to a standardized approach as much as possible in this field. In our industry, that is an open area of discussion.

Monge: *Regarding recycling, what are the impediments in this industry toward promoting better end-of-life?*

Haux: One basic thing we have to look at is whether we are considering direct packaging (contact-sensitive packaging) or secondary packaging because that will have an immediate impact on recyclability or the end-of-use phase. We believe that the best end-of-life option is always to keep the material in the loop. From our perspective, the preferable option is to design material for circularity so that we can take it back and recycle it mechanically. If that cannot be done, chemical recycling is a good alternative. We at Südpack say that we should try to prevent incineration wherever possible. But we have to look at how materials are used in different phases of development; I think that's very important.

One hurdle for the industry to negotiate — and that's along the whole value chain — is to start implementing the logistics and the infrastructure to be able to take materials back. It makes no sense to ship material over thousands of kilometers just to send it along into the next loop. There's a lot to do, which can be accomplished only if we all partner together: This requires partnerships along the entire value chain.

Monge: *Moving on to logistics, how do you manage to recycle film that has been exposed to biohazardous material? Is that achieved through post–life-cycle sterilization, and does the residue compromise the quality of recycled film?*

Barbaroux: First, I emphasize that not all our products are biohazardous after use. The first target

There's a lot to do, which can be accomplished only if we all partner together: This requires partnerships along the ENTIRE VALUE CHAIN.

is to start recycling material that is not biocontaminated, which is why we are working and collaborating with customers to understand what is truly biocontaminated and what could be diverted from incineration.

In parallel, we are exploring different options for recycling contaminated products. For example, steam sterilization or autoclaving would not be the best option for SU bags because the film will melt, preventing further disconnection and sorting of materials and components, ending in poor product quality postuse. Also, autoclaving is highly energy-demanding, so we have to consider the value chain and how to optimize a process to minimize its environmental impact.

Monge: *Is there a waste stream for recycling postuse products today? What can be produced with recycled film, and where can it be used?*

Barbaroux: There is a difference between what is recyclable and what can be recycled at scale. The composition of the Flexsafe multilayer film allows it to be recycled in the standard polyethylene waste stream like any other polyethylene packaging film, with quality equivalent to pristine polyethylene. But that is not the case for our S40 film, for instance, which is a laminated film with a mix of components that makes it too complex to be mechanically recycled. Theoretically, the Flexsafe film, because of its composition, can be recycled. The resulting material could be used in any application that allows recycled polyethylene. At Sartorius, postindustrial and internal waste goes back into a loop where the recycled content is not critical — for packaging applications, for instance.

Recycling at scale is something different; a recycler must exist close to a facility where the products are being manufactured so that materials don't need to be shipped back and forth after use. The recycler will have to handle the film after it has been disconnected and recycle it with sufficient quality to make it worth the effort.

The difficulty is in closing the gap. We know that, theoretically, materials can be recycled. However, we need first to collect nonhazardous bags, disconnect

The unique Flexsafe bag-in-shell system provides superior protection during drug substance handling.

COMPANY PROFILES

Sartorius is a major player in the global single-use bioprocess systems market with a product portfolio offering innovative solutions to support more efficient, robust, and sustainable bioprocessing.

Südpack is an internationally operating family business based in southern Germany. It offers a range of products in the field of recyclable films based on polymer structures.

va-Q-tec is a dynamic high-technology company that has been pioneering in the development of innovative solutions in the insulation industry since 2001. It offers energy efficient, space saving, and environmentally friendly vacuum insulation panels.

Michigan State University (MSU) is one of the largest public research universities in the United States operating its own large-scale power supply with multiple industrial steam boilers and turbines.

Genentech, a member of the Roche Group, is a biotechnology company dedicated to pursuing groundbreaking science to discover and develop medicines for people with serious and life-threatening diseases.

Daniel Fulford, senior sustainability program manager, Genentech (LEFT) and Nate Verhanovitz, performance engineer, Michigan State University (RIGHT)

Eco-Design at Sartorius

Maxicaps MR: The next generation of Maxicaps has been reassessed with an eco-design approach aimed at optimizing connectivity between the capsules. The new concept offers the same quality with more efficient use of materials, reduced plastic use, and low-volume packaging. The modifications represent up to 63% less material weight and 15 kilograms less plastic compared to the first generation.

Resolute BioSMB: The BioSMB multicolumn chromatography system enables up to 30% reduced water use due to higher binding capacity. It also achieves a 50–70% reduction in resin volume attributable to better resin use thanks to the higher cycling rate.

and collect the film, and store the film for a given time until the collection volume is sufficient to send to recyclers. If we don't have a quantity that is big enough, the film will be mixed with other plastics, and then we will lose both quality and value. We have to collaborate to close the gap between recyclable and recycled.

Logistics

Monge: *Medicines must be shipped constantly across the globe. It's not always possible to manufacture drug products right next to a patient's door. When considering improvements to shipping solutions and workflows, what parameters have the greatest impact on the environment?*

von Wysiecki: Three points need to be considered. The first point is that companies need to identify their demand and select the optimum solution to meet it. They need to consider the entire life cycle of a product. Multiuse and SU solutions are available, both with their advantages and disadvantages. The second point, in regards to a multiuse solution, is that a global rental network is ideal: Because product needs to be transported by truck from an airport to a production site, short distances are key to reducing such emissions. The third point relates to air freight. Here, weight becomes key because it has the biggest impact on CO_2 emissions during a flight.

At Sartorius, postindustrial and internal waste goes back into a loop where the recycled content is not critical — for PACKAGING APPLICATIONS, for instance.

Regulations

Monge: *In terms of logistics and sustainable shipments, what specific regulations need to be taken into account?*

von Wysiecki: In the supply chain industry, strict regulations apply to transports and shipments with dry ice. Airlines have individual targets or regulations; most allow 200 kg of dry ice per flight and packaging unit. This is a very difficult issue for packaging and shipment companies. Therefore, for example, va-Q-tec is working with phase-change materials so that we can eliminate dry ice from the supply chain. We can offer transport from cryotemperatures to room temperature without dry ice. If dry ice is required, then we work with vacuum insulation panels to reduce the amount necessary for such transport.

Prioritizing Sustainability During Product Development

Monge: *You mentioned that new technologies are designed with sustainability in mind. Could you give an example of a technology design criterion that you apply?*

Alaria: When we're evaluating our current portfolio to develop next-generation products, we apply an eco-design approach. We want to start, of course, with functionality: A product needs to be if not equal to, then better than the one before. We want to make sure that we choose the right materials for both product and packaging. This includes a carbon footprint assessment, working with our partners to ensure that they are supporting us in reducing our impact and looking at the circularity at end of life. That means thinking about, for example, potential disassembly options to help a customer deal with a product at the end of its life.

Considerations also can include the shape of a product because that influences transport and shipment. Imagine putting two pieces or two products instead of just one in one pallet; that will simplify and streamline transport and reduce the associated emissions. There are many other parameters that we include when we develop products and are defining new approaches.

The Power of Next-Generation Solutions

Monge: *Can you provide examples of how you successfully transitioned to SU technology and saw significant reductions in the environmental impact of your manufacturing facilities as a result?*

Fulford: We've just constructed a clinical supply center using only SU solutions. It's the first ballroom with end-to-end processes, so it incorporates cell culture all the way to purification. We are very excited about it. Water use has gone down by about 80%. Clean-in-place also has gone away, and we no longer have to pretreat wastewater before we discharge it to our sanitary sewer system. Energy use also has gone down: We have an ISO 9 classification inside the ballroom because everything is enclosed, so we're not constantly pumping air in and out.

We are moving toward constructing a full-scale SU manufacturing facility in Oceanside, CA. We'll be breaking ground later this year and targeting sometime in 2026 to start operations in that facility. We are excited about that agile form of manufacturing and how it streamlines tech transfers, also.

We are currently looking at the final waste stream and how to manage that. We're starting to aggregate and analyze the waste stream, and we are finding that it is dynamic; it's unique. Sometimes it contains pharmaceuticals, sometimes it has other liquids, sometimes it doesn't — it depends on what's happening on the floor. We're spending a lot of time working with our technicians to see how they're manufacturing and how we want to manage that back-end waste.

Monge: *The figures on process intensification are also impressive. From your point of view, how fast is the industry adopting process intensification, and are sustainability targets an important part of end-user decision-making? We get the impression that people are trying to optimize or intensify certain steps to create closed, more compact systems in their manufacturing. Is that what you see in the facility that you just mentioned?*

Biostat STR single-use bioreactors are supported by automation and analytics software.

We have to **COLLABORATE** to close the gap between recyclable and recycled

Fulford: I think intensification is a gradual step (see the Case Study box on the next page). We have seen some life-cycle assessments (LCAs) that show an increased process mass intensity when using SU bags. That is exciting. As technology changes and we gain more experience with these systems, we get better at using them. Our PTD (pharma technical development) teams are also working more and more with this new technology. They're improving their understanding of the dynamics, and they're collaborating with Sartorius on how to proceed.

As we look at suppliers, from my point of view, Sartorius is leading this narrative right now. We're happy to be working with your teams because this work is complicated — there is no easy fix for this

UMetrics Suite of Data Analytics Tools Help Drive CO_2 Reduction

The SIMCA multivariate data analysis software from Sartorius has processed data and isolated results for utility production and consumption using over 20,000 variables for a major research university campus of more than 60,000 people.

From that data and using a phased approach, multivariate data analysis (MVDA) revealed plant repair and operational improvement opportunities that have been able to prevent substantial expense.

Phase 1, which was a pilot phase, achieved a recurring savings of approximately US$120,000 in a single year and prevented emissions of 780 metric tons CO_2e (carbon dioxide equivalent). Phase 2 work also prevented further costly equipment damage by identifying the root cause of lubrication problems on high-speed electrical equipment. Encouraged by the success of the pilot, phase 2 is presently in action with a more ambitious sustainability goal.

The goal in phase 2 is to save US$1 million a year and prevent approximately 10,000 metric tons CO_2e at prevailing fuel costs.

The diverse project team includes MSU plant engineering staff and faculty, students studying engineering, local utility providers, and Sartorius engineers and data scientists.

Nate Verhanovitz, performance engineer
Michigan State University

Case Study: Process Intensification

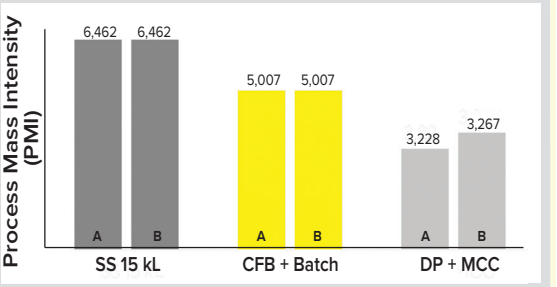
Process intensification describes a holistic framework for improving the overall efficiency of production. It offers greater volumetric productivity while reducing waste and energy consumption, contributing to improved sustainability (**3**).

In the biopharmaceutical industry, intensified processing can be applied both upstream and downstream. Upstream strategies have been the primary focus of intensification efforts so far and mainly involve perfusion cell culture, either in a seed train or in a production bioreactor. Downstream intensification strategies typically involve integration of several unit operations into one single flow-through step, creating continuous processes that are faster with higher yields.

To assess the impact of process intensification on sustainability measures, Sartorius performed an in-house study using the sustainability matrix feature within the industry-recognized BioSolve modeling software. In our studies, the most significant impact was a 50% reduction in process mass intensity (PMI) with both upstream and downstream intensification (and SU technologies) compared to traditional stainless steel operations (Figure 2).

Additionally, although cell culture media use increased in intensified operations, water consumption was still lower than in traditional processes. Downstream process steps (specifically chromatography steps) are the most water-intensive operations of an entire biologics manufacturing process train. Multicolumn chromatography (MCC) enables column overloading and thus increases resin use and reduces column size (**4**). MCC also results in up to a 50% reduction in buffer consumption, an often-overlooked area. Combining these strategies with inline buffer dilution reduces footprint because it allows for storage of higher concentration buffers.

Figure 2: Process intensification strategies help limit process mass intensity (PMI); (A) 300 kg/year and (B) 1,500 kg/year throughputs. PMI was measured for a traditional stainless-steel fed-batch process (SS 15kL) and two process intensification scenarios: an upstream SU concentrated fed-batch process followed by standard batch downstream process (CFB + Batch), and an SU dynamic perfusion (DP) process (continuous feed and harvest of the product through microfiltration), with downstream multi-column chromatography (DP + MCC). Data were generated using BioSolve modeling software.



In summary, higher-yielding processes that are completed in less time, with an optimized number of process steps, enable a smaller process footprint within a cleanroom. This creates more compact manufacturing facilities with lower HVAC requirement, driving significant reductions in environmental impact. Next-generation facilities will combine process intensification scenarios with single-use solutions to maximize efficiency and limit environmental impact.

This case study is excerpted from the Sartorius white paper, Driving Environmental Sustainability in the Biopharmaceutical Industry *(see the download box on page 2).*

As we expand our search for energy and water-conservation opportunities, we're further leveraging the SIMCA program as a KEY TOOL for drilling deeper into such options.

back-end kind of waste stream. It is important for us as a team to have a dialogue about upcycling and assessing chemical and mechanical recycling.

Monge: *How did the Sartorius Umetrics suite help you realize and document your emission reduction and cost saving overall?*

Verhanovitz: At Michigan State University, we used a tool called SIMCA from the Sartorius Umetrics suite to identify opportunities to run the plant more efficiently. That, of course, reduced Scope 1 emissions and saved fuel. We also can save significantly on the purchased electrical system, which helps us in Scope 2. And then we're looking at SIMCA online to automate that process going forward.

Monge: *And how quickly did you realize the potential of cost saving and the ability to meet sustainability goals? Was it quick, or did it take some figuring out?*

Verhanovitz: That's the surprising thing — it was quite rapid as far as such things go. We partnered with the Sartorius data analytics team. It provided some initial results from the data that we supplied, and then improvement opportunities were clear from that first meeting. It's like we jumped up from the meeting and ran out to the plant to change some

Single-Use Solutions in the Biomanufacturing Industry

SU technologies are increasingly used in modern biopharmaceutical manufacturing as an alternative to traditional stainless steel solutions because of their contributions toward reproducibility, flexibility, time efficiency, and safety. These technologies are implemented across the bioprocess workflow from cell line development to final filling, including storage bags, mixers, bioreactors, tubing, filters, chromatography systems, and sensors.

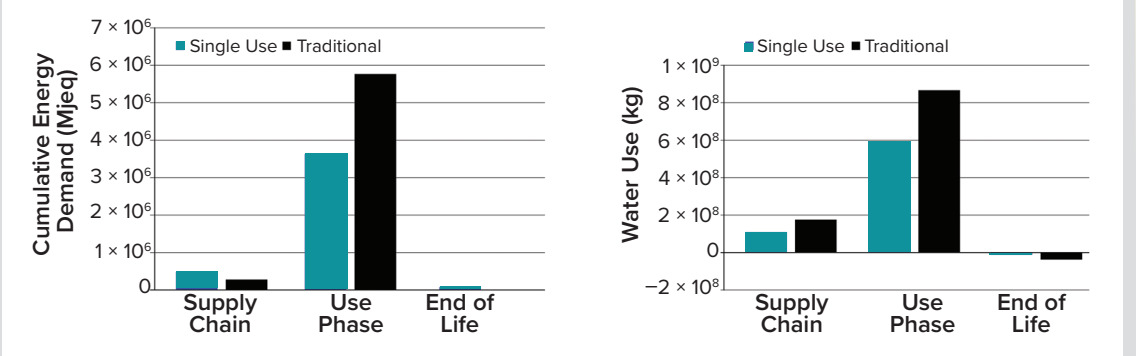
The adoption of SU technologies helps the industry reach environmental goals and strive against resource depletion, particularly by reducing water and energy consumption, emissions, and operating footprints (**5**) (Figure 3).

Reasons for industry adoption of SU technologies

- improved consistency in manufacturing processes
- flexibility to design a purpose-built facility and the ability to amend SU technologies as needed
- fast process deployment and changeover
- less initial investment in fixed equipment enabling significant cost-savings
- reduced water use due to the elimination of steaming and cleaning procedures (Figure 3)
- smaller facility footprint, which reduces the requirement for HVAC, the most significant factor for energy use in a facility. (**1, 6**)

This case study is taken from the Sartorius white paper, Driving Environmental Sustainability in the Biopharmaceutical Industry *(see the download box on page 2).*

Figure 3: The impact of single use on (LEFT) energy consumption and (RIGHT) water use (data from Reference 1 (above)



things. And, of course, that saved both fuel and emissions right away. Over time, we began doing that ourselves within the engineering team and then by reaching out to our students. We now have a couple of student groups trained to use the tool and join in the effort to meet our sustainability goals.

Monge: *How will you maintain and improve on fuel and emission savings moving forward?*

Verhanovitz: It's a phased approach, and our outreach gets a little bit wider every time. We've connected the SIMCA software to our entire utility historian, which is a real-time historian that stores multiple years of data for production and consumption of electricity and steam. Maintaining those gains is simple because all we need to do is compare the actual performance with the modeled performance. That allows us to pinpoint deviations.

As we expand our search for energy and water-conservation opportunities, we're further leveraging the SIMCA program as a key tool for drilling deeper into such options. We're getting ready to automate that software online, allowing engineers to refocus their efforts on upstream technologies.

We have talked about ambitious goals among the entire value chain, but only TRANSPARENCY and STANDARDIZATION of metrics create impact and a valuable collaborative approach.

Collaboration Is Key

Monge: *A number of industry forums are working on sustainability topics. Do you consider those to be the best platforms with which to work collaboratively toward sustainability?*

Alaria: Such cooperation is crucial. We now have,for example, the BioPhorum, Bio-Process

Figure 4: Key environmental sustainability themes identified by Sartorius

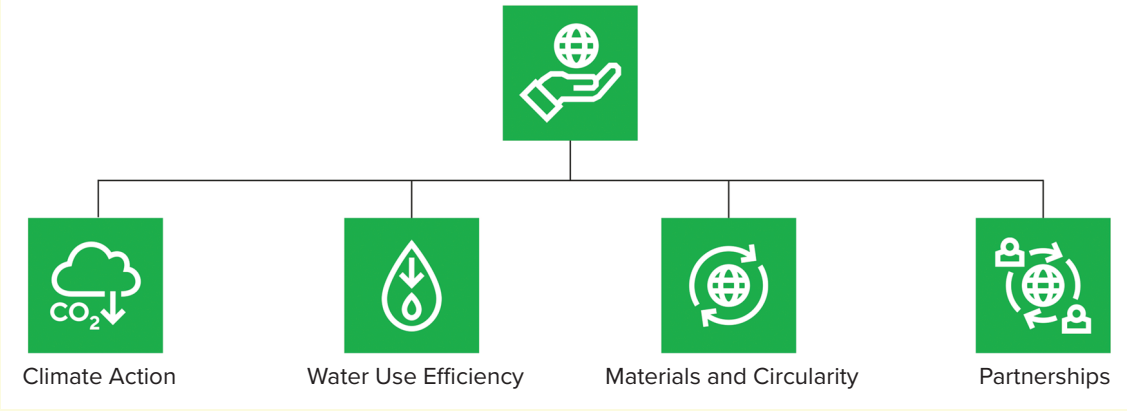
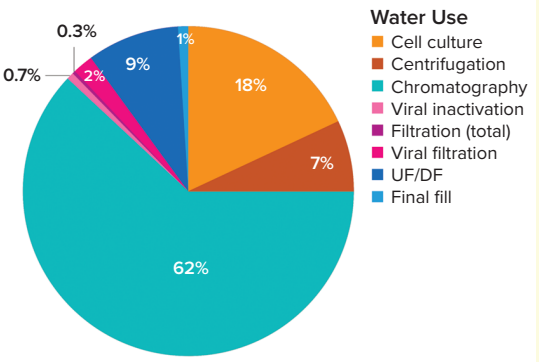


Figure 5: Total water use for each unit operation in a generic bioprocess; data include only process-related activities, not auxiliary steps such as clean-in-place.



Systems Alliance (BPSA), National Institute for Innovation in Manufacturing Biopharmaceuticals (NIIMBL), and many other industry groups that are engaged in these discussions. We try to bring different aspects of sustainability into conversations with all the partners involved.

von Wysiecki: I would like to be the ambassador for standardization. We have talked about ambitious goals among the entire value chain, but only transparency and standardization of metrics create impact and a valuable collaborative approach.

Final Remarks: Four Core Pillars

Front runners in the biopharmaceutical industry are expected to act responsibly and offer improved bioprocessing technologies. This means scoping resource-efficient and innovative technology solutions to transform scientific discoveries faster into patient care while progressing toward common sustainability goals.

The following section includes excerpts from the Sartorius 2023 white paper, wherein the authors discuss their approach to sustainability across four core pillars (Figure 4).

Core Themes Across Sartorius's Environmental Sustainability Approach

Sustainability has been part of Sartorius's DNA since its founding 150 years ago and is one of our key values. We are a major player in the global SU bioprocess systems market, with our product portfolio containing a range of innovative solutions to support more efficient, robust, and sustainable bioprocessing.

As a leading partner in the biopharmaceutical industry, Sartorius is committed to contributing to a future where more people have access to effective and affordable healthcare. At the same time, we are mindful of the environmental impact of our activities. In our white paper, we consider our environmental footprint over four core themes: climate action, water use efficiency, materials and circularity, and partnerships. We discuss how our bioprocess solutions and expertise empower biopharmaceutical manufacturers to make their own processes more sustainable by adopting SU technologies, improving process efficiency, and forging productive collaborations (see the "Single Use Solutions" box on the previous page).

Climate Action: As the industry responds to increased demand and competition with more efficient manufacturing strategies, we must consider the impact of those processes and manufacturing choices, above all, on the climate. As well as ambitious efforts to limit CO_2 emissions at our own production sites, we have been pivotal in supporting our customers to achieve their sustainability goals

Sartorius works toward the aspirational objectives of the **NEW PLASTICS ECONOMY,** which include design, responsible use, recycling capacity, and the use of recycled content.

by providing product or process solutions that help reduce their carbon footprints. Our product portfolio supports intensified processing, from minor adjustments within unit operations to building entire intensified manufacturing facilities.

Water-Use Efficiency: Biologics manufacturing is a water-intensive operation. Specifically, chromatography is the most water-intensive step, using more than three times the amount of water consumed during seed-train expansion and in the production bioreactor (Figure 5). Increasing productivity using multicolumn chromatography (MCC), replacing flow-through resins with polishing chromatography membranes, and implementing filtration products with superior wettability significantly reduces overall water and buffer consumption.

Materials and Circularity: Sterile SU plastic products are a core component of Sartorius's portfolio. However, with SU products come questions about how raw materials are sourced and what happens during a product's life cycle. Sartorius addresses those aspects and considers our products' environmental footprint and how we can foster circularity (**8**). Sartorius works toward the aspirational objectives of the New Plastics Economy (**9**), which include design, responsible use, recycling capacity, and the use of recycled content.

Partnerships: Partnerships within the biopharmaceutical industry are needed to achieve bioprocess sustainability goals that are transparently shared, harmonized, and standardized using comparable and equitable tools. Fostering collaborations with suppliers, working groups, and regulatory bodies is essential to build a robust sustainability framework. Sartorius collaborates with a number of industry advocacy, standards, and regulatory groups. We also have ongoing partnerships with, for example, Südpack (represented in the panel discussion by Valeska Haux) and va-Q-tec (represented by Moritz von Wysiecki).

We are keen to establish strong partnerships with all our suppliers and customers in this domain. If you are interested, please reach out to sustainability forum@sartorius.com.

References

1 Budzinski K, et al. Streamlined Life Cycle Assessment of Single Use Technologies in Biopharmaceutical Manufacture. *N. Biotechnol.* 68, 2022; 28–36; https://doi.org/10.1016/j.nbt.2022.01.002.

2 Monge M, et al. Driving Environmental Sustainability in the Biopharmaceutical Industry. *BioPharm Int.* Webcast, 2023; https://www.biopharminternational.com/view/driving-environmental-sustainability-in-the-biopharmaceutical-industry.

3 Sartorius. Process Intensification: Key Considerations and Expert Insights; https://www.sartorius.com/en/ebook-process-intensification-key-considerations-723616.

4 Mihal C. In with the New: Embracing Multicolumn Chromatography. *The Medicine Maker.* 2021; https://themedicinemaker.com/manufacture/in-with-the-new-embracing-multicolumn-chromatography.

5 Flanagan W, et al. An Environmental Life Cycle Assessment Comparing Single-Use and Conventional Process Technology. *BioPharm Int.* 8, 2011; https://www.biopharminternational.com/view/environmental-life-cycle-assessment-comparing-single-use-and-conventional-process-technology.

6 Cochet O, et al. A Sustainable, Single-Use Facility for Monoclonal Antibody Production. *BioProcess Int.* 11(11) 2013: 34–40.

7 Budzinski K, et al. Introduction of a Process Mass Intensity Metric for Biologics. *N. Biotechnol.* 49, 2019: 37–42; https://doi.org/10.1016/j.nbt.2018.07.005.

8 Sartorius. *GRI Report 2021*; https://www.sartorius.com/download/1273402/ssb-gri-bericht-en-2021-pdf-data.pdf.

9 Ellen MacArthur Foundation. *The New Plastics Economy: Rethinking the Future of Plastics*, 2014; https://ellenmacarthurfoundation.org/the-new-plastics-economy-rethinking-the-future-of-plastics.

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Driving Environmental Sustainability in the Biopharmaceutical Industry

Download the White Paper Now

We are keen to establish strong partnerships with all our suppliers and customers in this domain. If you are interested, please reach out to:

sustainabilityforum@sartorius.com

Take part in our survey and help us drive environmental sustainability in the biopharmaceutical industry.

Sustainability Survey