Expert View

SUSTAINABLE DRUG DELIVERY SYSTEMS: COLLABORATIVE INNOVATION TO SHRINK PHARMA'S PACKAGING FOOTPRINT

Maria Riccius and **Dr Uwe Hanenberg** of Recipharm explore how CDMOs are playing a pivotal role in driving drug delivery's transformation towards sustainability, examining the most promising advances and highlighting why collaborative innovation is essential to achieving measurable environmental gains, both within organisations and across the pharmaceutical value chain.

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As the pharmaceutical industry increasingly considers sustainability factors as a key facet of its products, drug delivery systems have emerged as a crucial, yet complex, area for environmental innovation. While small in form, components such as blister packs, vials, leaflets and tamper-evident seals have a disproportionately large environmental footprint, not only because of the materials used, but also due to the energy-intensive processes required to manufacture and assemble them.

Balancing sustainability with performance is no small feat – packaging must protect sensitive drug products from moisture, oxygen and light; maintain shelf life; and meet stringent regulatory and patient safety requirements. Traditionally, this has driven the use of robust, non renewable materials such as polyvinyl chloride (PVC) and aluminium foil. These materials, while highly functional, present recycling andemission challenges.

However, innovation is accelerating. Across the pharmaceutical ecosystem, drug developers, technology innovators and CDMOs are coming together to reimagine drug delivery systems through a sustainability lens. From transitioning to recyclable and lower-impact materials to re-engineering manufacturing processes to cut emissions, these efforts are starting to reshape the environmental profile of drug packaging.

THE PACKAGING PARADOX: SAFETY VERSUS SUSTAINABILITY

Pharmaceutical packaging is fundamentally engineered to protect. It shields medicines from degradation and contaminants; ensures correct dosage and safe administration; and provides critical regulatory and safety information to patients and healthcare providers. However, these life-saving functions often come at an environmental cost, resulting in a packaging paradox – the very materials that ensure product safety and patient wellbeing are often those least compatible with sustainability goals, for example:

- **PVC:** PVC is commonly used in blister packs and tamper-evident labels due to its strong barrier properties and transparency, which allows patients and healthcare providers to visually confirm the contents without opening the packaging. This visibility can help reduce errors and support product identification at the point of use. However, the high chlorine content in PVC contributes to persistent pollutants during both manufacturing and disposal, raising concerns over its long-term environmental impact.

- **Aluminium Foil:** Aluminium foil remains a staple in pharmaceutical packaging, especially for protecting sensitive formulations from light, oxygen and moisture. Despite its functional benefits, its production is energy-intensive, resulting in a substantial carbon footprint. This makes it one of the more problematic materials when evaluating packaging sustainability.

- **Paper-Based Leaflets and Labelling:** Leaflets and labels are vital for meeting regulatory requirements and

supporting the safe use of medicines, particularly by providing clear dosage instructions and warnings. However, in multilingual regions such as the EU, the need to include multiple languages often inflates leaflet size and packaging volume, generating excess material and increasing emissions from a production and distribution standpoint. As a result, even these seemingly minor components can carry a considerable environmental burden.

Beyond environmental concerns, the path to more sustainable packaging is further complicated by regulatory scrutiny. Any change to primary or secondary packaging, even if it is environmentally motivated, must undergo rigorous testing and receive regulatory approval to demonstrate that the new material maintains product stability, does not interact adversely with the formulation and continues to ensure patient safety. This can create long timelines and risk-averse mindsets around innovation, especially in global markets where regulatory harmonisation is limited.

However, stakeholders across the pharmaceutical sector are increasingly recognising that sustainability and safety do not have to be mutually exclusive. By investing in materials science, forging closer partnerships between innovators and CDMOs and aligning packaging innovations with evolving regulatory frameworks, the industry is beginning to tackle this paradox head-on.

KEY INNOVATIONS IN DRUG PACKAGING

Across the sector, drug developers and CDMOs are introducing new ways of enhancing sustainability without compromising on safety or regulatory compliance. These innovations are reshaping both primary and secondary packaging, and in many cases, delivering added value in the form of streamlined operations, reduced costs and improved patient experience.

One of the most visible areas of innovation is the shift away from traditional high-carbon materials. Companies are actively seeking alternatives to long-established packaging components such as PVC, polystyrene and aluminium foil – not only due to environmental concerns but also in response to emerging regulations on plastic use and recyclability.

For example, polyethylene, which generates less carbon dioxide than other polymers during manufacturing due to its simpler structure and lower processing temperatures, is being explored as a lower-impact substitute for tamper-evident seals and some types of blister packs. Polyethylene terephthalate (PET) is also being trialled as a replacement for polystyrene in blister packaging, due to its superior environmental profile. Furthermore, there is an ongoing search for an effective replacement for aluminium foil, which is one of the most carbon-intensive materials still widely used for barrier protection.

Lower-impact substrates are also replacing PVC in certain packaging components such as labels, with paper-based alternatives offering a more recyclable and less pollutive profile. However, this shift comes with important caveats – simply switching to paper does not eliminate waste. This is where digital innovation becomes an important complement to material change. In particular, the transition to electronic product information (ePI) is helping reduce the volume of printed material required in pharmaceutical packaging.

MINIMISING LABELLING WASTE WITH DIGITAL TOOLS

Printed leaflets, especially those required to meet multilingual regulatory mandates, can be a major source of paper waste and packaging bulk. To mitigate this, many pharmaceutical developers are collaborating with CDMO partners to implement ePI, a digital alternative that replaces physical leaflets with scannable QR codes. Patients can access dosage instructions, warnings and safety guidance on their mobile devices, ensuring the same level of regulatory compliance while drastically cutting down on printed material.

Beyond material reduction, ePI also offers operational advantages. Updates to product information can be made centrally

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and in real-time, helping manufacturers stay compliant across markets without the need for costly and wasteful reprinting. As regulatory support for ePI grows, particularly in the EU, where agencies are actively piloting digital labelling frameworks, it is becoming an increasingly viable strategy for improving packaging sustainability without compromising patient access to vital information.

ENHANCING RESOURCE EFFICIENCY IN PRODUCTION

Sustainability in packaging goes hand-in-hand with smarter manufacturing. CDMOs are investing in cleaner energy sources, upgrading infrastructure and optimising processes to reduce the total environmental footprint of drug production, from raw material handling to packaging line output. Examples of this include:

- Installing solar panels and pellet heating systems to power packaging lines with renewable energy
- Upgrading water purification and recycling systems to reduce water consumption in cleaning and cooling
- Introducing process automation and smarter equipment calibration to reduce waste, increase yields and lower energy intensity
- Developing closed-loop solvent recovery systems to capture and reuse production materials that would otherwise become hazardous waste.

By embedding environmental responsibility into everyday operations, CDMOs can create packaging workflows that are both more sustainable and more economically efficient. In doing so, they can create benefits that can be passed on to their pharmaceutical partners.

CDMOs AS SUSTAINABILITY PARTNERS: THE POWER OF CO-DEVELOPMENT

For pharmaceutical companies navigating the transition to more sustainable drug delivery systems, the road is rarely straightforward. Internal capacity constraints, evolving regulatory requirements, budget pressures and the imperative to maintain product safety all create barriers to swift or unilateral change, particularly for smaller or mid-sized firms. Against this backdrop, the role of CDMOs becomes not just supportive, but transformational.

CDMOs operate at the intersection of formulation, development and commercial manufacturing, making them uniquely placed to embed sustainability initiatives across the entire product lifecycle. Their infrastructure, technical expertise and cross-functional oversight can enable them to assess the environmental implications of material selection, optimise production processes to reduce waste and energy use and help sponsors interpret the regulatory pathways for implementing greener solutions. When involved early on in product planning, CDMOs can shape more sustainable drug production from the outset.

ALIGNING WITH VERIFIED CLIMATE TARGETS

As this strategic role evolves, CDMOs are also under increasing pressure to demonstrate their own environmental performance. In response, many are aligning with independently verified frameworks, such as the Science Based Targets initiative, which requires companies to commit to measurable emission reductions across Scopes 1, 2 and 3. For sponsors seeking trustworthy partners, such commitments signal a proactive and credible approach to sustainability.

For example, CDMOs participating in such initiatives are already making meaningful progress:

- **Scope 1 (Direct Emissions)**: Reductions are being driven through facility upgrades, increased energy efficiency and low-carbon equipment investments.
- **Scope 2 (Purchased Energy)**: Many CDMOs are moving towards full reliance on renewable electricity, with some on track to achieve Scope 2 neutrality by the end of the decade.
- **Scope 3 (Value Chain Emissions)**: These efforts often include supplier engagement, changes to packaging material sourcing and optimising logistics to reduce downstream impact.

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What makes these efforts meaningful is not just the internal impact, but the tangible benefits that progress like this can offer to pharma partners. Through co-development models, CDMOs can work alongside sponsors to identify opportunities for emission reductions within specific product pipelines – such as designing out PVC, streamlining packaging formats or implementing ePI. These initiatives are not add-ons but integral to the way projects must be scoped and delivered.

Crucially, sustainability must be embedded into internal governance. Environmental performance should be assessed within project management and change control alongside traditional metrics such as quality, cost and delivery timelines. This ensures that emission reductions are considered a strategic priority from day one, not a downstream retrofit.

By embedding these practices, CDMOs can help sponsors implement meaningful sustainability initiatives without needing to build the expertise or infrastructure in-house. As industry expectations around environmental performance continue to rise, collaboration at this level may become not only a differentiator but a prerequisite for bringing greener drug delivery systems to market.

INTEGRATING SUSTAINABILITY INTO EVERY DOSE

As the pharmaceutical industry moves toward a more sustainable future, drug delivery systems – and the materials and processes that support them – offer an immediate and high-impact opportunity for change. From rethinking packaging substrates to embracing digital labelling and cleaner production methods, progress is being made. However, scale and speed will depend on collaboration. With their operational breadth and technical insight, CDMOs are set to play a pivotal role in accelerating sustainable innovation across the product lifecycle. By embedding sustainability into the earliest stages of product development and ensuring that it runs through to commercial manufacture, industry can make meaningful strides in reducing its environmental footprint without compromising the quality, safety or accessibility of the therapies it delivers.

ABOUT THE COMPANY

Recipharm provides manufacturing services for pharmaceuticals in various dosage forms, including sterile fill-finish, oral solid dosage and biologics; clinical trial material development and manufacturing services; and pharmaceutical product development. Its Advanced Bio Division develops and commercialises advanced therapy medicinal products, performs preclinical to clinical projects, and offers commercial development and manufacturing for new biological modalities.