

Chapter 29

Advancing Circular Economy Through Ad-tech for Optimising Future Manufacturing

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Abstract

The proposed research explores the intersection of Ad-tech, predictive analytics, and circular economy (CE) principles to support manufacturers in transitioning to circular models. Our method introduces a digital platform that enables data-driven circular manufacturing by embedding consumer engagement strategies, behavioural analytics, and supply chain integration to close resource loops, extend product lifecycles, and reduce waste. The research aligns with Industry 5.0 and the United Nations Sustainable Development Goals and focuses on three key objectives: (1) enhancing resource efficiency using life cycle assessment (LCA) tools and real-time inventory monitoring, (2) promoting sustainable consumer behaviours through personalised Ad-tech, and (3) enabling cross-sectoral collaboration for reuse and recovery.

Keywords: *Circular Economy (CE), Ad-Tech & Consumer Engagement, Predictive Analytics, Data-Driven Manufacturing*

Introduction

The urgency of transitioning toward circular economy (CE) practices in manufacturing has grown significantly in response to the escalating climate crisis, resource depletion, and the inefficiencies of linear production models. CE frameworks promise to reduce waste, conserve raw materials, and enable sustainable growth through continuous reuse, recycling, and regeneration of products and resources. However, despite increasing attention, many brands and manufacturers struggle to adopt CE principles effectively due to operational constraints, limited consumer engagement, and a lack of scalable data infrastructure.

Digital transformation in manufacturing has introduced tools that enable greater automation, traceability, and efficiency. Yet these tools often have a narrow focus on supply chain or production improvements without integrating the behavioural dimension, necessary to close resource loops effectively. This research proposes a novel approach that incorporates Ad-tech strategies—traditionally used in consumer marketing—to bridge this gap. By embedding behavioural insights into predictive analytics and resource recovery, manufacturers can both optimise internal operations and influence external consumption patterns.

The proposed platform explores how these interdisciplinary technologies can facilitate systemic change in manufacturing by enabling dynamic inventory tracking, forecasting product return likelihood, and

nudging consumers toward sustainable behaviours. This paper outlines the foundational methods and early-stage findings that validate this model and sets the stage for future scalable adoption in the industry.

Background and Motivation

Manufacturers have long operated within a linear system of take-make-dispose, resulting in significant environmental and economic inefficiencies. In contrast, the circular economy model emphasises longevity, reuse, and regeneration. Yet the transition to CE has been slow due to challenges such as fragmented supply chains, underdeveloped data ecosystems, and low consumer participation in take-back or reuse programs.

Ad-tech platforms, known for their data-driven precision and personalization, offer a unique lens through which one can reimagine circular supply chains. These systems already track user behavior, preferences, and real-time feedback loops. When redirected toward sustainability goals, they can drive consumer participation in recycling, repair, and remanufacturing initiatives.

Furthermore, governments and institutions are pressurising on industries to adopt sustainable practices. Global initiatives such as the United Nations Sustainable Development Goals (SDGs), Industry 5.0 frameworks, and enforcement of regulations like Section 1557 of the Affordable Care Act create both the imperative and opportunity for innovation.

Verifiable Evidence Supporting Platform Claims

- **Behavioural AdTech Personalization:**

Research shows that behavioural targeting and personalization significantly improve consumer engagement and conversion outcomes. Industry analysis indicates that 71% of consumers expect personalized interactions, while 76% express frustration when content is not tailored to their preferences.¹ Additionally, large-scale advertising studies demonstrate that targeted campaigns can substantially outperform non-targeted approaches in both click-through rates and revenue generation.² These findings support the feasibility of leveraging AdTech to deliver sustainability-focused messaging to environmentally conscious consumers.

- **Circular metrics in marketing:**

Evidence from circular economy research indicates that consumers are more likely to select products when circular attributes—such as recyclability, durability, and reuse potential—are clearly communicated.³ This suggests that integrating circular performance indicators into

¹Anstine, “Consumer Acceptance of Products Made from Recycled Materials: A Scoping Review.” *Resources, Conservation & Recycling*, 186 (2000): 106533.

<https://doi.org/10.1016/j.resconrec.2022.106533>

²McKinsey & Company, “The Value of Getting Personalization Right—or Wrong—Is Multiplying,” 2022. Accessed June 30, 2025, <https://www.mckinsey.com>.

³BlueLithium (Yahoo! Advertising), “Study on Behavioral Targeting: 400 Million Impressions,” 2006. Accessed June 30, 2025, <https://www.yahooinc.com>.

marketing and advertising metrics can meaningfully influence purchasing decisions, reinforcing the role of data-driven communication in advancing circular consumption.

- **Consumer demand and feedback loops:**

Emerging research on digital engagement and advertising transparency demonstrates that consumer response is highly sensitive to how personalization is implemented. Studies show that acceptable and transparent targeting increases engagement, while overly intrusive or “creepy” personalization reduces effectiveness.⁴ This highlights the importance of ethical, user-centered AdTech strategies in building trust and enabling feedback-driven systems, which are critical for supporting demand-driven manufacturing and continuous product lifecycle optimization.

- Harvard Business School research (as featured in *Wired*) demonstrates that transparency in acceptable targeting increases engagement, while “creepy” approaches dampen response.

Method

This combines life-cycle assessment (LCA) tools, real-time inventory data, and Ad-tech-inspired predictive analytics to create a robust and scalable digital platform for circular manufacturing. The development of the platform followed an iterative prototyping model and simulated behavioural scenarios to evaluate the system's effectiveness.

First, LCA frameworks such as openLCA were integrated into the platform to map environmental impacts across each stage of the product lifecycle—from raw material sourcing to end-of-life. This enabled precise visibility into carbon emissions, water usage, and material depletion, allowing manufacturers to quantify benefits of circular actions.

Second, real-time inventory data were modelled to simulate how dynamic stock updates and product tracking could trigger reminders or incentives for product returns and repairs.

Third, predictive analytics and consumer segmentation algorithms were built on synthetic behavioural data, designed to mimic real-world engagement patterns. These models aimed to forecast the likelihood of sustainable actions, such as opting into take-back programs based on previous behaviour, demographics, and environmental values.

Platform-app Interconnection

The **AdTech engine** serves as the backend brain:

- It collects user data from the app and digital product IDs
- Feeds it into segmentation + targeting models
- Pushes campaigns across ad channels (Facebook, TikTok, in-app banners, email, etc.)
- Tracks return behaviour, A/B ad performance, sustainability KPIs, and user-level impact.

⁴Ellen MacArthur Foundation and Circle Economy, “The Importance of Circular Attributes for Consumer Choice of Fashion Products,” *Journal of Cleaner Production*, (2024), Accessed June 30, 2025, <https://www.sciencedirect.com>.

Product: Wearable Tech Jacket (Fashion + Electronics)

A smart jacket that tracks activity and integrates with circular care/return services.

Circular Model:

- Built-in sensor module can be removed and reused
- Fabric recycled or remade by brand partner
- Subscription model for upgrades or seasonal swaps

AdTech Integration:

- Push ads for module upgrade after 6 months
- Ads for free return kit once jacket wear reaches threshold
- Partnership campaigns: “Recycle jacket, get 3 months of Spotify Premium” (Figure 1).

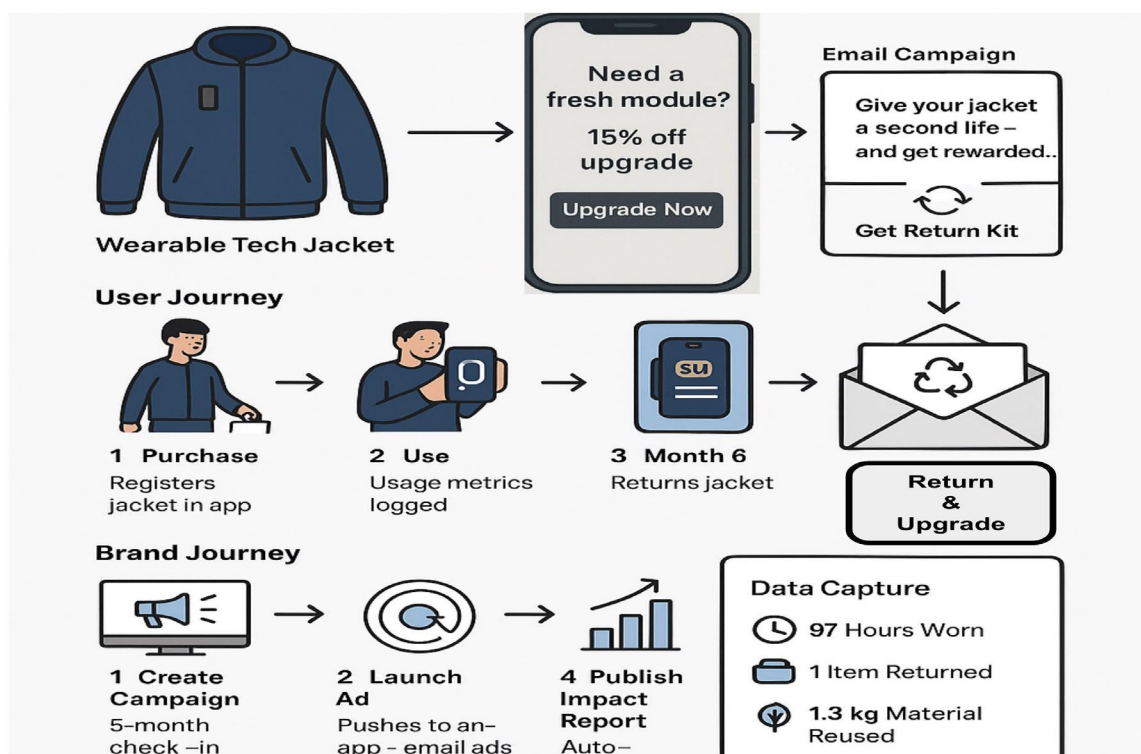


Figure 1: Wearable Tech Jacket with circular care/return services (User Journey + Brand Journey)

Prototype Journey (User + Brand Interaction)

Step	Action	Trigger	AdTech Role
Purchase	User buys jacket (in-store or online)	Digital product ID is activated	Registers jacket through the app
Use	Jacket tracks activity, time-worn	Usage metrics logged	Lifecycle segmentation begins
Month	Jacket has seen heavy use	>80 wear hours logged	App shows: ‘Need a fresh module? 15% off upgrade’
Month	Fabric shows signs of wear	Based on smart textile diagnostics	Push: ‘Return your jacket and get a \$40 voucher’
Return	User initiates return	QR code scan → shipment label	Brand logs impact (CO ₂ saved, fabric reclaimed)

Step	Action	Trigger	AdTech Role
Reward	User receives loyalty points	Verified return	Dynamic ad offers a new colour version or accessory

User Journey (Individual App)

Prototype Journey (Brand Interaction)

Finally, messaging engines, borrowed from Ad-tech, were configured to test personalised consumer nudges through simulated A/B testing. For example, consumers classified as ‘early adopters’ of sustainable behaviour received targeted content designed to reinforce recycling habits.

Step	Action	AdTech Input	Outcome
Creat campaign	‘6-month check-in’ campaign for core module upgrade	Lifecycle cohort: 1500 users	Geo-filters applied (NYC + LA)
Launch Ad	Pushes to in-app + Meta ads + email	Dynamic content: Module still under warranty vs expired	Real-time A/B test of conversion copy
Track return rate	Monitor 30-day engagement	Usage vs return correlation	Optimise ad cadence for next release
Publish impact report	‘Customers returned 63% of jackets before 9 months’	Auto-generated data from platform	Improves ESG marketing credibility

Brand Journey (Company Dashboard)

Methods

To assess the potential impact of the proposed AdTech-powered circular economy platform, a rule-based behavioural simulation was conducted modeling 10,000 user journeys through the lifecycle of a wearable tech jacket. Users were segmented by both behavioural engagement (e.g., passive and eco-motivated) and by product price tier (low, mid, high). Simulated platform interventions included predictive nudging ads, lifecycle-based personalization, and in-app sustainability prompts tied to the jacket's digital ID.

Each price tier influenced behavioural assumptions:

- **Low-cost products** (< \$100) were associated with lower return and repair motivation, requiring stronger incentives.
- **Mid-priced products** (\$100–\$250) exhibited the highest response rates to lifecycle ads and circular campaigns.
- **High-cost products** (> \$300) triggered longer ownership periods and higher repair engagement, though return frequency was lower.

Behavioural triggers were informed by data benchmarks from platforms, such as Patagonia Worn Wear, Loop by TerraCycle, and Fairphone, as well as standard AdTech performance metrics (e.g., dynamic ad CTRs, email open/click-through rates). Circularity outcomes, such as material recovery, lifecycle extension, and manufacturing waste reduction, were extrapolated based on user actions and mapped

against closed-loop system assumptions. This multi-dimensional simulation illustrates the platform's efficacy across different economic product categories.

Finally, the project establishes a technical blueprint for how marketing and operational technologies can converge to solve sustainability challenges. Unlike traditional CE tools that focus solely on materials, this approach emphasises behavioural and informational dynamics^{5,6}.

Results and Discussion

The platform was evaluated using early-stage simulations across synthetic product and consumer datasets. Initial findings support the hypothesis that an integrated CE-Ad-tech framework can deliver measurable improvements in resource efficiency and behaviour change (Figure 2).



Figure 2: Description of User + Brand Interaction.

Conclusion

This chapter proposes and validates a new paradigm for circular manufacturing that integrates Ad-tech, predictive analytics, and lifecycle analysis to deliver measurable environmental and operational gains. Early-stage validation of the proposed platform suggests strong potential to reduce waste, improve resource recovery, and change consumer behaviour through personalization and feedback loops.

⁵Kim, Tami, et al., "Online Ad Targeting Works—As Long as It's Not Creepy," *Wired*, 2018. Accessed June 30, 2025, <https://www.wired.com>.

⁶Reis, Joe and Matt Housley, *Fundamentals of Data Engineering: Plan and Build Robust Data Systems*, (Sebastopol, CA: O'Reilly Media, 2022), [https://soclibrary.futa.edu.ng/books/Fundamentals%20of%20Data%20Engineering%20\(Reis,%20JoeHousley,%20Matt\)%20\(Z-Library\).pdf](https://soclibrary.futa.edu.ng/books/Fundamentals%20of%20Data%20Engineering%20(Reis,%20JoeHousley,%20Matt)%20(Z-Library).pdf).

By leveraging tools traditionally used in marketing and repurposing them for sustainable consumption, the platform enables a proactive, data-driven shift in how manufacturers design and deliver products. It goes beyond compliance to create business value and environmental resilience. The approach also aligns with emerging standards for responsible AI and green supply chains.

Future research will focus on implementing real-world pilots in sectors such as electronics and healthcare, integrating ESG reporting standards, and exploring partnerships with recycling logistics providers. The ultimate vision is to create a cross-sector, interoperable infrastructure that accelerates the global transition to circular economy manufacturing models.

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