Extended Abstract
6th PLATE 2025 Conference
Aalborg, Denmark, 2-4 July 2025

Regenerated cellulose fibers synthesized with recycled textiles: A circular bioeconomy milestone for material longevity or another fiber overproduction escalation?

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Keywords: Circular Economy; Bioeconomy; Textile; Man-Made Cellulosic Fibers (MMCF); Circular Fashion.

Introduction

Fashion is a major contributor to environmental degradation, accounting for 10% of global greenhouse gas emissions, 20% of freshwater pollution, and 35% of microplastics released into the oceans (EC, 2022). These environmental impacts have worsened due to the global expansion of textile fiber production, which has doubled since 1998. This growth has been largely driven by the rise of fast fashion, trade liberalization policies, and the decreasing lifespan of garments — now worn fewer than eight times before being discarded (EMF, 2017; Niinimäki et al., 2020). Moreover, this increase in fiber production has been largely fueled by the rise of fossil-derived fibers, which now account for over 67% of total fiber output (Textile Exchange, 2024).

In response, man-made or regenerated cellulosic fibers (MMCFs or RCFs) have emerged as a potential strategy. Their promotion fits circular economy and bioeconomy frameworks aimed at reducing dependence on fossil-based fibers. Sourced from renewable resources like forests, MMCFs also offer the potential to incorporate cotton and cellulose-based textile waste, enhancing material longevity (EC, 2018;2020;2022). Currently, most RCFs are synthesized with mechanically recycled cotton to produce lyocell (Abrishami et al., 2024); their future potential lies in chemical recycling technologies, such as ionic liquids (El Seoud et al., 2020; Haslinger et al., 2019; Ma et al., 2018). The use of recycled cellulose pulp holds significant innovation potential and is expected to grow significantly (Textile Exchange, 2024). Reusing cellulose fibers already in circulation in the market has been argued to be a this material longevity strategy and could reduce dependency on virgin raw materials like cotton and forests.

Between 2000 and 2018, global dissolving pulp production increased by 6.3%, with 85% used for MMCFs—outpacing cotton (1.3%) and synthetic fibers (5.1%) (FAOSTAT, 2024; Kallio, 2021). Growth accelerated from 2012 to 2023, with production doubling. Haemmerle identified this "cellulose gap" already in 2011, accurately forecasting the trend, with his predictions for 2015 and 2020 achieving 93% and 91% accuracy, respectively (Haemmerle, 2011; Textile Exchange, 2017, 2024).

However, despite their "sustainable" label, MMCFs face significant barriers regarding production impacts, product lifespan, recyclability, and potential rebound effects. Environmental impact and lifespan vary by fiber type—for instance, viscose, which represents 80% of MMCF production, often has a greater environmental footprint than fossil-based fibers. Meanwhile, lyocell is considered one of the most sustainable textiles due to greener chemicals in its production and more conscious forest management (Shen et al., 2010). Nevertheless, the industry faces criticism for poor forest management, particularly monocultures like eucalyptus, which threaten biodiversity and is involved in deforestation while also contributing to chemical water pollution (Changing Markets, 2020).

Recycling technologies remain limited—only 1% of textiles are downcycled. Currently, recycled content in new MMCFs barely reaches 20%, requiring the remainder to be virgin viscose or lyocell (e.g., Circulose by Renewcell, Tencel, Refibra x Lenzing, Ioncell) (Cao, 2021; Piribauer & Bartl, 2019). Furthermore, studies show that the environmental benefits of biological materials can be outweighed by the negative impacts of reduced product durability (Hildebrandt et al., 2021).

Objectives and Methodology

This study aims to identify the drivers and barriers influencing the growth of MMCFs and assess their potential to support a circular transformation in the textile sector. It combines a comprehensive literature review with econometric ARIMAX modeling to analyze both traditional factors (e.g., forest and cotton industries) and emerging ones (e.g., recycled textiles and the cellulosic industry) affecting MMCF growth and their alignment with circular economy principles.

Given the lack of data on MMCF garment or material lifespan, the study specifically explores the potential of incorporating recycled textile waste into MMCF production as a material longevity strategy. It also examines the broader implications of this integration for transforming the textile, forest, and cellulosic sectors, assuming other factors in the current system continue their existing trajectory.

Conclusions

The potential of MMCFs lies in their technical properties and the resources used—particularly the reuse of textile waste. However, this study highlights that coupling recycling and bio-based strategies does not automatically ensure material longevity or environmental benefits. Key concerns include limited recycling technology, the need to blend recycled content with virgin MMCFs, and the environmental impacts of forestry practices and chemical use. The growing use of MMCFs in fast fashion and blended fibers, produced in high volumes with short lifespans, risks creating rebound effects. Moreover, there is a lack of research on MMCF garment longevity and little progress in improving their recyclability.

The results shows MMCFs offer economic and ecological opportunities, their ability to drive material a systemic circular transformation is limited. The findings suggest that MMCFs could improve eco-efficiency but fail to tackle core issues of overproduction, descarbonization and sustainable forest management.

Achieving meaningful change requires integrated strategies prioritizing extended product and material lifespans, with recycling as a complementary approach. Biodegradability, though marketable, is not enough. Long-term durability enabled by extended product use is crucial for environmental performance (Deckers et al., 2023).

For real circular transformation, MMCF promotion must be supported by policies that foster sustainable production and consumption, emphasizing product durability and material quality. Only through a holistic approach can the textile sector truly transition to a circular economy.

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