CRITICAL CASE STUDY — DRAFT DIAGRAM

Textile-to-Textile Recycling: Nucycl® vs Infinna™

EXAMPLE 1

EVRNU NUCYCL®

Regenerated lyocell fibre from cotton-rich textile waste

KEY SUSTAINABILITY CLAIMS

- Uses discarded cotton-rich textiles and production waste
- Transforms waste into a high-performance lyocell fibre
- Claims the fibre can be recycled repeatedly
- Offers an alternative to virgin cotton and polyester

VS

EXAMPLE 2

INFINITED FIBER — INFINNA™

Cellulose-carbamate fibre regenerated from textile waste

KEY SUSTAINABILITY CLAIMS

- Made from textile waste, including cotton-rich post-consumer waste
- Designed to feel soft and natural like cotton
- Contains no plastic and can be recycled with textile waste
- Claims to support textile circularity at industrial scale

COMPARISON CRITERION: SYSTEMS THINKING + CIRCULAR ECONOMY

INPUT	PROCESS	OUTPUT	END OF LIFE	SCALE + ACCESS
What type of textile waste can enter the system?	Chemicals, energy, water and material losses	Fibre quality, durability and blend requirements	Can the finished garment be collected and recycled again?	Infrastructure, cost, commercial capacity and transparency

EARLY QUESTIONS / UNCERTAINTIES

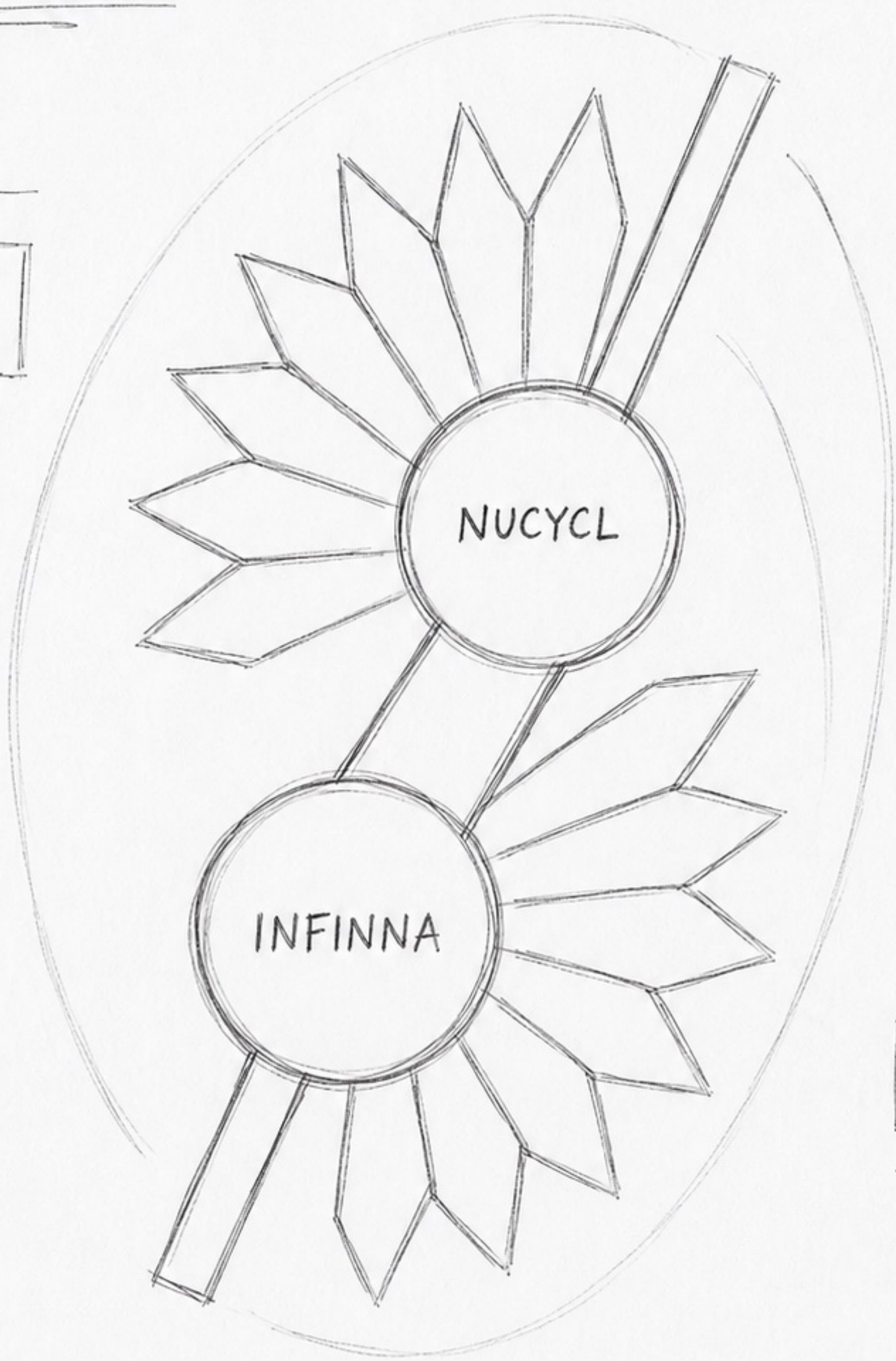
- How well do the systems handle dyes, elastane and blended fabrics?
- Are repeated-recycling claims proven outside pilot projects?
- Does better fibre technology reduce overproduction and consumption?
- Who is responsible for garment collection and sorting?

EARLY DESIGN INTERVENTION

SHARED MATERIAL PASSPORT + RETURN SYSTEM

- Add a QR code to each garment showing fibre content and recycling instructions.
- Create shared collection points accepted by multiple fashion brands.
- Direct garments to the recycling process that matches their fibre composition.
- Give users repair, resale or return options before recycling.

SPINNING A CIRCULAR FUTURE



PRODUCT COMPARISON · CIRCULAR TEXTILES

SPINNING A CIRCULAR FUTURE

Nucycl® × Infinna™ · a life-cycle systems comparison

PROJECT SUMMARY

Both technologies regenerate cellulose from textile waste. Their routes differ in feedstock purity, sorting burden, chemistry, fibre form and readiness for scale.

02
T2T

THE WASTE GAP

92M TONNES / YEAR

- GLOBAL WASTE
- LANDFILL
- SORTABLE
- CLOSED LOOP

FEEDSTOCK CHAIN

- **POST-CONSUMER** garments
- **PRE-CONSUMER** factory scraps
- **HARD PARTS** zips / trims

WHERE BURDEN MOVES

- **SORTING** purity upstream
- **CHEMISTRY** recovery downstream
- **WASHING** water + energy
- **DATA** identity across cycles

TECHNOLOGY FIT

NUCYCL®

Clean cotton-rich feedstock; continuous high-tenacity filament.

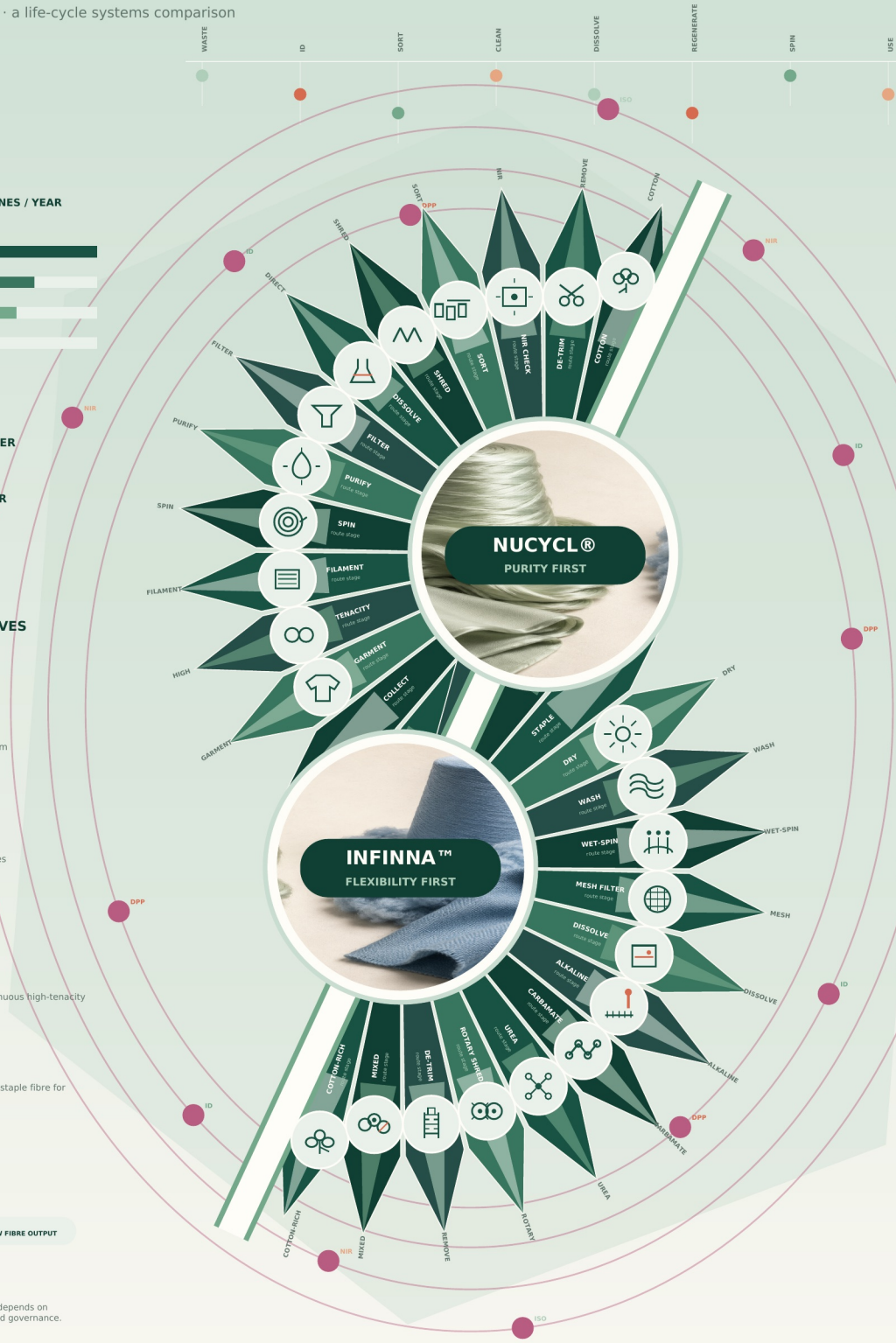
INFINNA™

More flexible cotton-rich streams; staple fibre for existing mills.

SHARED FEATURES

- CELLULOSE RECOVERY
- NEW FIBRE OUTPUT
- TEXTILE RE-ENTRY

No universal winner: performance depends on feedstock quality, infrastructure and governance.



SYSTEM SUPPORT

1. **DPP** verified fibre data
2. **RFID / QR** product identity
3. **NIR** physical check
4. **SORT** route to recycler
5. **STANDARDS** shared taxonomy
6. **OWNERSHIP** access + control
7. **MILLS** commercial uptake

OUTCOMES

- **IDENTIFY** material passport
- **ROUTE** automated sorting
- **RECOVER** two chemistries
- **RE-ENTER** mill-ready fibre

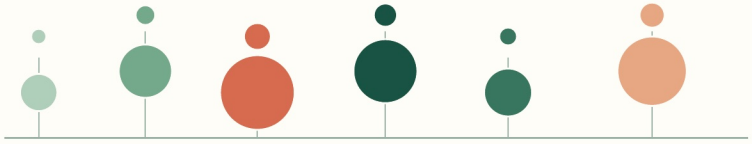
BURDEN PROFILE

SORT / PURITY

CHEMISTRY / WASH

NUCYCL®

INFRASTRUCTURE ACROSS THE LIFE CYCLE



KEY

- SHARED
- NUCYCL
- INFINNA

Sources: Evrnu (2023); Infinited Fiber Company (2023)

CIRCULARITY REQUIRES MATERIAL + DATA + GOVERNANCE.

Systemic Trade-offs in Closed-Loop Textiles: A Critical Life-Cycle Comparison of Evrnu Nucycl® and Infinna™ Regenerated Fibres

Title: Beyond Incremental Substitution: Evaluating Chemical Textile-to-Textile Recycling and Digital Traceability Governance

1. Introduction & Background

Global textile production generates approximately 92 million tonnes of waste annually, with less than 1% being recycled back into new clothing in a closed loop (Niinimäki et al., 2020). The old linear model of fashion consumption - 'take, make and dispose' - has led to excessive extraction of new-energy materials, substantial pollution from toxic chemicals and large-scale landfill waste, high water consumption, etc. Although the mechanical recycling process is now employed by commercial waste recovery enterprises, it shortens the length and alters the structure of staple fibres through severe mechanical shredding; as a result, the downcycled products have reduced economic, functional and material values.

Due to the limitations of physical damage, chemical textile-to-textile (T2T) recycling technology has recently been proposed to address the problem of circular fashion. By breaking down post-consumer textile waste at the molecular level, chemical recycling recovers high-purity cellulose or polymer building blocks to produce regenerated man-made cellulosic fibres (MMCF) or synthetic filaments with virgin-equivalent mechanical properties. Although the realisation of large-scale chemical T2T recycling is a technical problem in solvent chemistry, it also involves all sorts of trade-offs among feedstock purity thresholds, chemical processing intensity, energy load and multi-stakeholder governance across disaggregated global value chains (Tonkinwise, 2015).

2. Methodology & Analytical Framework

Critically analyse the circularity of chemical T2T using a dual-prism comparative system of feedstock purity and chemical processing load. Chemical recycling is not universally superior, so we have selected two leading industrial technologies in the regenerated cellulose sector for this study: *Evrnu's Nucycl®* and *Infinited* Fiber Company's *Infinna™*.

The design of sustainability theory evaluation at multiple levels (Pilgaard, 2019; Tonkinwise, 2015) gradually moves from micro-level molecular deconstruction to

macro-level socio-technical infrastructure and governance systems. To solve the fundamental problem of collecting, identifying and sorting heterogeneous post-consumer textile waste, a strategic Design intervention has been put forward in this paper: integrating Digital Product Passports (DPP) with Near-Infrared (NIR) automated sorting. The location and analysis of this intervention are within the institutional governance system of the Australian Fashion Council's Seamless clothing stewardship scheme (Australian Fashion Council, n.d.).

3. Critical Analysis & Technology Case Studies

3.1 Case A: Evrnu's Nucycl® Technology

Evrnu's Nucycl® technology represents a high-purity cellulose dissolution pathway designed to generate premium continuous filament fibers from post-consumer cotton waste (Evrnu, 2023). Nucycl is operated under a modified lyocell-type direct-dissolution process; thus, cellulosic waste is not severely depolymerised and the recovered pulp can be re-extruded as high-tensile, pristine filament yarns.

However, Nucycl does not use chemical modification and is therefore required to have high-purity cellulosic raw materials. Non-cellulosic contaminants, such as elastane blends, polyester stitching, hydrophobic coatings and metal trims, cause severe clogging of the extrusion spinneret and damage the structure of the spun fibre. Therefore, Case A adds to the operating costs of upstream pre-treatment and intensive physical sorting by requiring mechanical trim removal and chemical blend separation before the feedstock can be used in the dissolution reactor.

3.2 Case B: Infinited Fiber Company's Infinna™ Technology

In contrast, Infinited Fiber Company's Infinna™ is produced via a chemical route involving cellulose carbamate chemistry. Infinna chemically modifies cotton-rich post-consumer textile waste streams by reacting them with urea under thermal treatment to produce a stable cellulose carbamate intermediate (Infinited Fiber Company, 2023). This intermediate is soluble in mild alkaline solutions and can be wet-spun into various cotton-like regenerated staple fibres suitable for conventional spinning equipment.

Carbamate conversion has a relatively high tolerance to impurities compared with direct-dissolution systems. Chemical modification can be used to process heterogeneous cotton-rich blends, absorb various post-consumer streams that would otherwise foul lyocell-type reactors, etc. However, this flexibility comes at the cost of a higher operating cost, more chemical reagent consumption (such as urea handling), and additional wastewater treatment requirements in the carbamate synthesis and regeneration steps.

3.3 Comparative Synthesis & Infrastructure Trade-offs

Nucycl® and Infinna™ are in fundamentally different systems of the chemical T2T landscape and, therefore, have different feedstock purities and processing levels.

Nucycl reduces the amount of downstream chemical processing, energy consumption and chemical reagent use by requiring ultra-pure feedstock, thus shifting the economic and operational burden upstream to sorting and mechanical pre-treatment facilities (Evrnu, 2023; Haslinger et al., 2019). Informa receives lower-grade, mixed post-consumer waste streams, adds a chemical modification step downstream, and must perform more extensive chemical synthesis and washing to deal with feedstock variations.

Neither technology is a universally better option. Nucycl is better suited for high-value, closed-loop technical applications that require continuous high-tenacity filament, while Infinna is a pragmatic and highly scalable bridge for processing bulk, lower-grade post-consumer textile waste streams.

Expansion of these chemical processes must also meet the demand for supporting regional infrastructure. Infinna has more feedstock options for large-scale sorting bases but is also a multi-step chemical modification process with higher upfront costs. On the other hand, Nucycl's high-purity requirement demands significant investment in local, high-precision optical sorting technology before it can be economically feasible (Geissdoerfer et al., 2017).

4. Strategic Design Intervention: Digital Product Passports & Automated Governance

Since both Nucycl® and Infinna™ have strict chemical contamination limits, manual garment sorting must be used to avoid problems such as incorrect or missing care labels, and thus the scale-up of chemical T2T recycling is limited. To bridge the gap between post-consumer waste and the requirements of chemical processing, this essay puts forward a strategic design intervention: to integrate Digital Product Passports (DPP), RFID/QR codes, and Near-Infrared (NIR) automated sorting under an extended producer responsibility (EPR) system (Englund et al., 2018; Australian Fashion Council, n.d.).

Digital Product Passports (DPPs) are employed to create a supportive infrastructure for RFID and optical tag applications in NIR optical scanning across all stages of the garment's life cycle. Fashion brands are adding verified fibre-composition data, chemical-finish records and dye information to a digital garment passport in production. At the end of their life cycle, clothes enter post-consumer waste; regional automated sorting centres, in conjunction with national stewardship systems, have

been equipped with digital tag readers and NIR optical scanners. While DPP and RFID systems provide verified product metadata directly from the manufacturer, NIR scanners cross-check the physical fibre composition of automatically sorted items to detect untagged, modified or mislabelled products (Englund et al., 2018).

Digital-physical integration can reduce sorting errors and lower the cross-contamination risk for chemical recyclers; an open-source material traceability system will be created in the value chain (Brown & Harris, 2015). Under the Seamless scheme, brand eco-contributions (4c per garment levy) will fund capital expenditure for regional sorting hardware and open-source DPP database architecture, establish a multi-stakeholder governance model, and share operational responsibility among apparel brands, waste collectors and chemical recyclers (Australian Fashion Council, n.d.).

5. Critical Reflection: Unintended Consequences & Systemic Limits

Dunne and Raby (2013) used speculative design to explore the problems that new technology has created and found some deficiencies in the system.

Firstly, physical tags, scannable QR codes and optical markers are prone to damage from prolonged wear, washing or deliberate removal by consumers during extended use of the clothing. If there is no physical-digital tag integrity, unlabelled post-consumer items will not be recognised by the automated sorting line and will thus be treated as general waste.

High-tech chemical recycling may also be subject to the classic circular economy rebound effect (Zink & Geyer, 2017). By presenting chemical recycling as an infinite technical solution, the fashion industry may be legitimizing continuous overproduction and hyper-consumption, thus reinforcing the fast-fashion business model under the guise of technological sustainability (Chapman, 2015). If consumers and brands believe that clothing can be perpetually regenerated at the molecular level without environmental damage, emotional detachment and a higher frequency of clothing replacement may occur, thus offsetting the ecological benefits of chemical recycling infrastructure.

Lastly, the compliance and onboarding costs of the Digital Product Passport infrastructure are relatively high for small and medium-sized fashion brands and local manufacturers. If there are no targeted financial subsidies and open-access data standards provided by the governing body, a high-technology barrier may lead to market concentration and favour multinational fast-fashion conglomerates with abundant capital (Australian Fashion Council, n.d.).

Material constraints and governance friction over data ownership in the Digital Product Passport are also problems. Brands are reluctant to reveal their private fibre blends or commercial supply chain partners on open-source tracing networks. Without such data transparency, there may be an information asymmetry between high-end fashion conglomerates and regional waste-sorting enterprises, and thus, the joint accountability required by stewardship models will not be realised (Dahlbo et al., 2017).

6. Conclusion

Chemical textile-to-textile recycling technologies, such as Evrnu's Nucycl® and Infinited Fibre's Infinna™, have developed a method to avoid the problem of physical damage in traditional mechanical downcycling through molecular mechanisms. Material circularity cannot be achieved by chemical engineering alone in practice.

To realise scalable, closed-loop fashion systems, connect micro-level molecular processes with macro-level socio-technical governance and link Digital Product Passports, automated NIR optical sorting, and extended producer responsibility schemes such as *Seamless* (Australian Fashion Council, n.d.). However, the technical intervention should not be regarded as an unlimited-growth license. In order to achieve the goal of an environmentally friendly consumption system and prevent the problem of rebound effects (UN SDG 12, 2015), chemical recycling should be combined with emotionally enduring design, transparent governance and substantial reductions in global fashion overproduction.

References

Australian Fashion Council. (n.d.). *Seamless clothing stewardship scheme*. https://ausfashioncouncil.com/program/seamless/

Brown, V. A., & Harris, J. A. (2015). A collective mind for a just and sustainable future. In A. Fuad-Luke, A.-L. Hirscher, & K. Moebus (Eds.), *Agents of alternatives: Re-designing our realities* (pp. 46–57). Cultural-Ecological Publications.

Chapman, J. (2015). *Emotionally durable design: Objects, experiences and empathy* (2nd ed.). Routledge. https://doi.org/10.4324/9781315738802

Dahlbo, H., Aalto, K., Eskelinen, H., & Salmenperä, H. (2017). Increasing textile circulation—Consequences and challenges. *Journal of Cleaner Production*, 135, 1286–1294. https://doi.org/10.1016/j.jclepro.2016.06.170

Dunne, A., & Raby, F. (2013). *Speculative everything: Design, fiction, and social dreaming* (pp. vii, 1–9). MIT Press.

Englund, F., Wedin, H., Ribul, M., de la Motte, H., & Östlund, Å. (2018). *Textile tagging to enable automated sorting and beyond: A report to facilitate an active dialogue within the circular textile industry* (Mistra Future Fashion Report 2018:1). RISE Research Institutes of Sweden. https://mistrafuturefashion.com/wp-content/uploads/2018/06/Textile-tagging-Mistra-Future-Fashion-Report-2018.1.pdf

Evrnu. (2023). *Nucycl® technology*. https://www.evrnu.com/nucycl

Geissdoerfer, M., Savaget, P., Bocken, N. M., & Hultink, E. J. (2017). The circular economy: A new sustainability paradigm? *Journal of Cleaner Production*, 143, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048

Haslinger, S., Hummel, M., Anghelescu-Hakala, A., Määttänen, M., & Sixta, H. (2019). Upcycling of cotton polyester blended textile waste to new man-made cellulose fibers. *Waste Management*, 97, 88–96. https://doi.org/10.1016/j.wasman.2019.07.040

Infinited Fiber Company. (2023). *Our technology*. https://infinitedfiber.com/our-technology/

Niinimäki, K., Peters, G., Dahlbo, H., Perry, P., Rissanen, T., & Gwilt, A. (2020). The environmental price of fast fashion. *Nature Reviews Earth & Environment*, 1(4), 189–200. https://doi.org/10.1038/s43017-020-0039-9

Pilgaard, M. (2019). *How to design for sustainability part 2: Different tactics and scales* (pp. 1–17). Strategic Design Press.

Tonkinwise, C. (2015). Radical sustainable innovation. In *Design for sustainability* (pp. 1–18). Routledge.

United Nations. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*. UN Publishing. https://sdgs.un.org/2030agenda

Zink, T., & Geyer, R. (2017). Circular economy rebound. *Journal of Industrial Ecology*, 21(3), 593–602. https://doi.org/10.1111/jiec.12545

DDES9014 Research Journal

Entry	Author(s)	Year	Title	Type of Source	Key Points	Page / Section	Notes	Usefulness to My Research / Design Practice	Link / DOI	Related Concept
1	Tonkinwise, C.	2015	Radical Sustainable Innovation	Book chapter	True sustainability requires radical systemic innovation rather than incremental material substitutions.	pp. 1–18	Tonkinwise argues that eco-efficiency alone can perpetuate linear consumption.	Directly supports my Method and Compare sections by proving that replacing virgin cotton with regenerated fibres is insufficient without systemic sorting infrastructure.	https://doi.org/10.4324/9781315694290	Systemic innovation / Design tactics
2	Pilgaard, M.	2019	How to Design for Sustainability Part 2 - Different Tactics and Scales	Book chapter	Design for sustainability operates across multiple scales, from micro-level material choices to macro-level socio-technical systems.	pp. 1–17	Pilgaard provides a structured taxonomy of sustainable design tactics at product, system, and infrastructure scales.	Provides the theoretical framework to bridge my analysis from micro-level molecular deconstruction to macro-level infrastructure.	Course Reading / Strategic Design Press	Design scales & tactics / Circular economy
3	Brown, V. A., & Harris, J. A.	2015	A Collective Mind for a Just and Sustainable Future	Book chapter	Achieving complex sustainability goals requires collective thinking and multi-stakeholder governance across public and private sectors.	pp. 46–57	Focuses on how distributed agency and transdisciplinary collaboration solve systemic locks in socio-ecological systems.	Informs my Strategic Intervention model by defining clear roles for Brands (data entry), Australian Fashion Council (standards), and Recyclers (sorting).	Course Reading / Cultural-Ecological Publications	Collective governance / Stakeholder integration
4	Dunne, A., & Raby, F.	2013	Speculative Everything: Design, Fiction, and Social Dreaming	Book chapter	Speculative design acts as a tool to provoke critical reflection on unintended consequences and complex socio-technical futures.	pp. vii, 1–9	Emphasizes using speculative scenarios to challenge optimistic technological narratives and reveal systemic vulnerabilities.	Used in my Strategic Intervention section to critically analyze potential unintended side effects, such as label wear-and-tear and rebound effects.	https://mitpress.mit.edu/9780262019842	Speculative design / Unintended consequences
5	Chapman, J.	2015	Emotionally Durable Design: Objects, Experiences and Empathy	Book	Physical and chemical circularity must address emotional durability; reducing waste requires countering consumer detachment.	pp. 21–30	Chapman demonstrates that technical recyclability does not curb fast fashion consumption if emotional obsolescence remains unaddressed.	Complements my conclusion by highlighting that closed-loop technology must be paired with emotional durability to prevent market rebound.	https://doi.org/10.4324/9781315738802	Emotionally durable design / Obsolescence
6	Haslinger, S., et al.	2019	Upcycling of cotton polyester blended textile waste to new man-made cellulose fibers	Journal article	Demonstrates cellulose recovery from cotton-polyester blended textile waste, establishing key parameters for chemical pre-treatment and fiber recovery.	Waste Management, 97, 88–96	Provides empirical chemical evidence on recovering regenerated cellulose from blended textile waste streams.	Supports the general feasibility of chemical cellulose recovery from blended waste, establishing the foundation for molecular recycling comparisons.	https://doi.org/10.1016/j.wasman.2019.07.040	Cellulose regeneration / Blended waste recycling
7	Niinimäki, K., et al.	2020	The environmental price of fast fashion	Journal article	Synthesizes global textile waste generation (92M tonnes/yr), water use, energy intensity, and environmental impacts of linear fashion production.	Nature Reviews Earth & Environment, 1(4), 189–200	Seminal review detailing global textile landfill volumes and the urgent necessity of T2T chemical recycling.	Establishes the global crisis background in my Introduction and grounds the urgent need for systemic circular intervention.	https://doi.org/10.1038/s43017-020-0039-9	Fast fashion impacts / Systemic waste
8	Evrnu	2023	Nucycl® Technology	Web page	Outlines Evrnu's proprietary regenerated lyocell-type fiber technology from post-consumer cotton waste, highlighting high-tensile filament properties and feedstock purity requirements.	Official Website & Tech Specs	Official manufacturer documentation for Nucycl® process characteristics and purity inputs.	Directly grounds Case A by defining Nucycl's high-purity input requirement and continuous filament output.	https://www.evrnu.com/nucycl	Lyocell regeneration / High-purity feedstock
9	Infinited Fiber Company	2023	Our Technology	Web page	Details Infinna's cellulose carbamate technology utilizing urea modification to transform cotton-rich textile waste into versatile regenerated staple fibers.	Official Website & Process Overview	Official manufacturer details on urea modification and cotton-rich feedstock tolerance (~88% cotton-rich).	Directly grounds Case B by explaining Infinna's feedstock flexibility and carbamate chemistry.	https://infinitedfiber.com/our-technology/	Cellulose carbamate / Feedstock flexibility
10	Englund, F., et al.	2018	Textile Tagging to Enable Automated Sorting and Beyond	Report	Analyzes textile tagging technologies (DPP, RFID, NIR) to facilitate automated sorting and support circular textile infrastructure.	Mistra Future Fashion Report 2018:1	Provides robust, peer-reviewed/institutional support for digital tagging and automated NIR sorting.	Directly supports the Strategic Intervention section by grounding the feasibility of automated sorting networks.	https://mistrafuturefashion.com/wp-content/uploads/2018/06/Textile-tagging-Mistra-Future-Fashion-Report-2018.1.pdf	Automated sorting / Digital tagging / DPP