

Supplementary Material

How do we change what we can't describe? A comprehensive Framework of User Behaviours in a materials' circular economy.

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Table S1. Framework of User Circular Behaviours, including definitions

Stage	Function	Purpose	Action	(Channel, if multiple)	Definition of action
GET	Avoid acquiring item	Avoid need for item	Make do / go without item		User avoids the need to obtain item by going wholly without or with less
			Use (up) existing items		User avoids the need to obtain an item by (re)using or first fully using up an existing item
			Use item sparingly		User delays the need to obtain an item by using existing item sparingly
			Make item self		User makes item themselves from materials already on hand
		Get access to item without ownership	Borrow item	Personal networks	User obtains temporary possession of item from personal connection with intention of giving back
				Community initiative	User obtains temporary possession of item from a community sharing initiative, with agreement to give back (for free or nominal cost)
			Hire / rent / lease item		User obtains temporary possession of item for a specified period of time in exchange for payment (including hire, rent, lease and commercial sharing services / micro hire)
			Get item through as-a-service		User opts to buy a digital alternative to a tangible item
			Get item digitally		User utilises / outsources to a service provider to avoid acquiring new item
			Outsource to service		User obtains access to or benefit from an item owned by a provider in exchange for payment (eg. pay-per-use, performance purchasing agreement, etc)
	Minimise acquisition impact	Get item second-hand	Rescue used item		User collects or salvages an item informally from discards
			Receive second-hand item		User receives a second-hand item free from another person (eg. Hand-me-down, freecycle, etc)
			Buy second-hand item	Source second-hand from someone	User buys a previously used item off another person (online or in-person)
				Buy from second-hand store	User buys a previously used item from a second-hand store
				Buy refurbished / reconditioned item	User buys a previously used item from a supplier which has been tested, serviced and/or repaired as necessary (eg. refurbished, reconditioned, etc)
		Buy item from circular materials	Buy item made from reused material		User purposely buys an item made from reused material (recovered material that is used in virtually same condition for original purpose)
			Buy item made from reclaimed material		User purposely buys an item made from reclaimed material (recovered material that with minor alteration can be used for a different purpose)
			Buy item made from recycled material		User purposely buys an item made from recycled material (recovered material that has been reprocessed)
			Buy item made from restorative material		User purposely buys an item made from restorative material (waste material recovered from the environment)
		Buy item built to last	Buy item that is durable		User purposely buys an item that has longer expected life or extended warranty
			Buy item that is reusable		User purposely buys an item that is designed for multiple use
			Buy item that is repairable		User purposely buys an item that is repairable through existing channels
			Buy item that is upgradable		User purposely buys an item designed to be upgraded over time to function better than original specifications
			Buy item that is dismantlable		User purposely buys an item designed to be dismantled at end of use/life, enabling reuse of components / refurbish / remanufacture
			Buy item that is recyclable		User purposely buys an item designed to be recycled at end of life (ie. separable into materials, which are eligible for recycling)

Stage	Function	Purpose	Action	(Channel, if multiple)	Definition of action
USE	Optimise item use	Use item yourself	Reuse own item		User continues to use item they own multiple times in original form for original function
			Use item from a reuse service		User participates in a scheme that enables multiple uses (by self and others) of an item which is 'owned' by the scheme provider
			Repurpose own item		User extends use of an item by finding a new function, with or without minor modifications
		Share own item with others	Lend own item	Personal networks	User loans an item not currently in use to own connection for temporary use with intention of getting back
				Peer-sharing scheme	User makes an item not currently in use available for the general public's use through a facilitated peer-to-peer sharing platform
			Swap own item with item from another		User gives item away in exchange for receiving a like item in return
	Extend working life of item	Retain item function / value	Preserve item		User preserves an item by using and/or storing it in an appropriate manner
			Maintain item	Self (DIY)	User keeps an item operating suitably by taking actions themselves that care for it
				Third-party	User keeps an item operating suitably by having a third-party service the item
				Brand	User keeps an item operating suitably by having a original supplier service the item
			Repair item	Self (DIY)	User acts themselves to return an item to working use after it breaks or ceases being functional
				Third-party	User has a third-party service return an item to working use after it breaks or ceases being functional
				Brand	User has original supplier return an item to working use after it breaks or ceases being functional
		Increase item function / value	Upgrade components	Self (DIY)	User acts themselves to increase the function of an item over original specifications by replacing components / hardware, and where relevant firmware / software
				Third-party	User has a third-party increase the function of an item over original specifications by replacing components / hardware, and where relevant firmware / software
				Brand	User has original supplier increase the function of an item over original specifications by replacing components / hardware, and where relevant firmware / software
			Upcycle item		User increases the value and/or function of an item through modification
		Return for same use	Return item for repair/replacement		User return item to original supplier and receive same (repaired) or similar (new replacement) back
PASS ON	Divest item for next use	Rehome for next use	Sell item		At end of use, user sells still usable item to someone else at a price, through online or physical/in-person platform
			Give item away	(Re)Gift	At end of use, user gives away still usable item to another person as a gift
				Hand-me-down	At end of use, user gives away still usable item to a personal connection for free
				Offer for free	At end of use, user offers still usable item to the public for free
			Donate item		At end of use, user donates a still usable item to an altruistic second-hand redistributor / reseller
		Return item for next use	Return item for resale		At end of use, user returns still usable item to original supplier for resale
			Return item for repair & resale		At end of use, user returns potentially usable item to original supplier for repair and resale
	Discard item for next life	Return for next life	Return item for disassembly		At end of life, user returns item to original supplier for components harvesting
		Pass on for next life	Sell or give away item for parts / repurposing		At end of life, user gives away for parts (for free or at a price)
			Correctly dispose item for recycling / recovery		At end of life, user correctly dispose into appropriate waste management system

Table S2. Preliminary typology of Upstream circular behaviours, including definitions

Stage	Function	Purpose	Action	Definition of action
PROVIDE	Produce circular items	Design to last	Design for multiple use (flexible/modular, reusable, resellable)	(Re)design product to enable reuse / resale by Users
			Design for extended use (durability, attachment)	(Re)design products for longer functional and/or aesthetic lifespan
			Design for extended life (repairability, upgradability, value retention)	(Re)design products for to enable repair and upgrade by Users
			Design for next use (component disassembly)	(Re)design product to enable dismantling for refurbish, remanufacture, reassembly
			Design for next life (material disassembly)	(Re)design product to enable material separation, sorting and reprocessing
		Produce efficiently	Design out production waste	Design production process(es) to eliminate or minimise waste (eg. lean manufacturing, reuse of by-products, etc)
			Dematerialise (lightweight)	Design product to use significantly less resources to produce.
			Digitise	Replace physical product with digital product/service offering
			Design efficient products	Design products that consume significantly less resources during use
			Refurbish	Repair or otherwise restore a used product to original function.
			Remanufacture	Rebuild a used product to original, 'as new' specifications using reused, repaired and/or new components.
			Make with existing components	Use returned / recovered components in production of new items
			Utilise by-products as inputs	Produce a project using some or all materials sourced from by-products of other processes
			Make with recycled content	Produce a product using some or all recycled materials instead of virgin materials.
		Bundle enabling services	Provide extended guarantees	Provide sufficient guarantees of expected life beyond the usual (provided by manufacturer)
			Enable repair/upgrade	Makes spare parts, specs and/or tools available to enable for DIY or third-party repair or upgrade of products
			Provide end-of-use return	Provide free drop-off/collection of still usable/repairable products for resale (provided by manufacturer)
			Provide end-of-use disposal	Provide free drop-off/collection of unusable products for disassembly / recycling (provided by manufacturer)
	Supply circular items	Circular business models	Resell used/repaired products	Provide previously used items for sale, including repairing first
			Retain ownership	Provide item to customer without transferring ownership (eg. hire, lease, sharing, pay-per-use, product-as-service, performance purchasing, etc)
			Include bundled services ('servitise')	Provide additional services to extend item use/life (free /included in price) eg. maintenance, repair, end-of-life return
			Provide extended guarantees	Provide sufficient guarantees of extended life beyond the usual (provider by retailer)
			Provide end-of-use return	Provide free drop-off/collection of still usable/repairable products for resale (provided by retailer)
			Provide end-of-use disposal	Provide free drop-off/collection of unusable products for disassembly / recycling (provided by retailer)
		Bundle enabling services	Provide resale functionality	Provide 'digital passport' or similar functionality to allow clear identification of product for resale
			Provide peer-to-peer sharing platform	Provide platform to enable users to share their items with other users
			Provide peer-to-peer resale platform	Provide platform to enable users to onsell their items to other users
			Offer maintenance/repair services	Offer maintenance and repair services for durable good
			Provide maintenance/repair spare parts and tools	Make spare parts and/or tools available for DIY repair by users
			Provide collection points	Provide collection points (locations, infrastructure) to enable people to working and/or broken items away for redistribution, repair, disassembly, recycling, etc

Table S3. Preliminary typology of Downstream circular behaviours, including definitions

Stage	Function	Purpose	Action	Definition of action
RECIRCULATE	Consolidate	Gather	Collect	Collect and consolidate products sold and/or donated
			Salvage	Salvage usable, repairable, repurposable or dismantlable products from discards intended for waste stream
			Sort	Sort / triage for resale, repair, repurpose and/or disassembly
			Disassemble / harvest	Disassemble or deconstruct products to harvest parts / components
	Recirculate	Onsell	Onsell working products	Onsell or pass on products in usable condition for resale (same function)
			Onsell repairable products	Onsell or pass on products in repairable condition, for repair and resale (same function)
			Onsell repurposeable products	Onsell or pass on products that can be repurposed (different function)
			Onsell components	Onsell or pass on parts/components for refurbishment or remanufacture
			Onsell materials for recycling or recovery	Onsell or pass on materials for material / chemical recycling or energy recovery
		Process for next use	Resale / redistribution	Resale / redistribution / reuse in same condition
			Repair / recondition	Restore to working condition for resale/ redistribution
			Component reuse / reassembly	Disassemble for component reuse / reassembly
			Remanufacture / refurbish	Disassemble / deconstruct for component repair / product remanufacture
		Process for next life	Mechanical Recycling	Shredding/crushing or melting product back into raw material (upcycle, closed loop, open loop/ downcycle)
			Feedstock / chemical recycling	Turning material back into base chemicals
		Recover	Energy / fuel recovery	Treating waste to create electricity, heat or fuel