Over the Rainbow: Sharing a cross-disciplinary philosophy of waste through spectrum visualisation

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Abstract: Waste is a material problem and a cultural condition. Many philosophies and visualisation resources exist for addressing waste such as waste hierarchies and circular economy diagrams. These diagrams, however, are not always enough to represent the intrinsic complexities related to waste systems or the interactions that exist between current and potential interventions. In this paper we contribute an original framework for understanding waste and propose a visualisation of waste as a spectrum of possibilities rather than as a series of discrete, disconnected interventions. The Waste Rainbow invites users to “plot” interventions and to think about these interventions and their relationships with the system on multiple stages of the life of an object.

Keywords: waste; design; circular economy; transdisciplinarity

1. Introduction

From the moment we wake up in the morning to the minute we fall asleep we generate some sort of waste in the world. Be it an annual spring cleaning or the everyday bits of “invisible” disposals such as food scraps, packaging, unwanted objects or body waste. In fact, even when we sleep we are still releasing old skin from our bodies. Waste is a condition of all living things, as part of the cycles of life, we consume resources, process them and dispose of what is not useful. Humans have excelled in this process, extending the consumption and processing of materials much beyond that of the necessities of our bodies and lives. We consume what we need and what we don’t need. Some of what we need is processed and given a lifetime of use, other items are used or contemplated for just a few moments before being disposed of without second thoughts. Social scientists, anthropologists and thinkers from multiple disciplines have warned us and commented on the consequences of the paradigm of growth and overconsumption from as early as 1960’s (Fry, 2009; Humes, 2012; Packard, 1960; Strasser, 2000). Today, consuming and throwing “out” is ubiquitous, desirable, stimulated and feels good. Yet as we consume and throw away our waste accumulates in the outskirts of the cities either in landfills or waiting for a chance to be recycled.
Although managing waste is a perennial human task, witnessed in ancient middens to modern landfills, in the present day the problem of waste has become far more pressing. As environmental degradation accelerates, waste from overproduction and overconsumption is both a cause and a symptom of unsustainability. The reduce, reuse, recycle mantra of the past twenty years has evolved into the proposition of the circular economy, in which waste must be ‘designed out’ of the system.

Within this context, we propose a new conceptual framework to understand, visualise and manage waste reduction interventions and policy. Our framework is based on a systemic understanding of waste and we use complexity and resilience theory to explain and visualise the multiple states of circularity of matter before it falls into landfill state—the state of waste from which there is no recovery or the energy necessary for recovery is too high to be feasible. Our framework, the ‘Waste Rainbow’ embeds the synergy between multiple disciplines that need to work together to tackle the state of waste. It can also accommodate the connections between the different states and different types of waste (whether organic, e-waste, plastic, textiles), which are often tackled separately, but are too intimately connected.

1.1 Context
Queensland University of Technology (QUT) is a major university in Brisbane with a strong focus on applied research. Researchers collaborate as part of the Institute for Future Environments (IFE) from disciplines within science, technology, engineering and mathematics (STEM) as well as disciplines within humanities, arts and social sciences (HASS). Since 2017, a growing community of researchers have formed a shared interest in tackling the problem of waste. Current research projects are focused on various waste streams including plastics, textiles, food and organic waste, e-waste and construction waste. Team members come from STEM disciplines including polymer chemistry, microbial biotechnology, materials science and robotics. HASS researchers are from disciplines including law, marketing, sociology, visual communication and fashion design. Given both the diversity of waste streams and the variety of disciplines involved, research projects are also diverse. Examples include qualitative investigations into government policies around plastic waste, a study on community food waste, numerous engineering projects converting different forms of waste (e.g. agricultural, other organic, textiles) to value-added products, and design-led research with an end-user focus in preventing household plastic waste. As designers, the authors saw an opportunity to map and order the varied activities underway within our transdisciplinary research group under a coherent narrative. The visualisation developed, the Waste Rainbow, is presented in this paper.

1.2 Methods of inquiry
The methods of this paper comprise a literature and contextual review of waste, the circular economy and how these concepts are visually represented; assessment of the efficacy of other visualisations of waste and the circular economy; and design research methods for
development of a fresh visualisation. Visualisations were located through image search engines using the key words of ‘diagram; waste’ and ‘diagram; circular economy.’

Given the context described above, three criteria were developed for assessing the efficacy of a visualisation: (i) the framework should be transferable to a variety of waste streams, (ii) the framework should be able to encompass both HASS and STEM methodologies for waste research and (iii) the framework should allow for the visualisation of connections between multiple interventions.

This paper is structured as follows: First, literature on waste and the circular economy is presented. Second, authors provide a contextual review and assessment of visualisations of waste and the circular economy. Third, the authors outline the design process for the Waste Rainbow, a visual representation of a specific approach to waste research. Last, a short assessment of the framework and its visualisation is presented, highlighting its benefits and weaknesses, through examples of its use in research practice.

2. Understanding waste

Waste can refer to any matter that has become surplus to requirements. Waste can also refer to wasted time, wasted energy, wasted work hours. Every system, whether biological or human-made, creates waste, inevitably by-products or leftovers decay or fall out of usage (Moser 2002). Waste in its physical form, whether waste water, waste plastics, food waste, or human biological waste, is associated with pollution, disgust and damage, and “garbage is civilisation’s ... shadow” (Scanlan 2005, 179). Anthropologist Mary Douglas (1966), in her analysis of society’s need to create systems of order, memorably refers to dirt as “matter out of place. People ascribe value to objects, things, materials for diverse social, economic, historical and cultural reasons. In human society, things become waste when they are seen or found outside of those cultural or economic systems of value and become ‘matter out of place’, unwanted and valueless. Yet waste is not the definitive state of being of that matter, but rather a state into which it has been ‘put’ through human decision-making. Matter can move in and out of this state of waste depending on context.

Within environmental narratives, waste is the by-product of overproduction and overconsumption, a visible marker of pollution and profound environmental damage. It is a symptom of contemporary society (Humes 2012, Strasser 1999). As matter viewed as abject, waste must be sent ‘away’ for others to deal with. Frequently the scavengers, gleaners and the ragpickers, those who deal with waste, are those on the margins of society. In the Global North, waste is exported to the Global South. Yet while out of sight, out of mind, waste still exists somewhere—there is really no ‘out’ for waste.

Waste is often framed as a problem that needs to be ‘solved’ with a range of strategies and approaches to tackle it. In the many ‘R’s associated with waste management, waste must be reduced and avoided through refusing, reusing, repairing, remanufacturing, as well as recycling and reclaiming materials. As cultural theorist Gay Hawkins (2006, ix) writes, the drive for recycling as a strategy for tackling waste “have implicated waste in the formation
of new circuits of guilt and conscience and practices of self-regulation”. Individuals are implicated for their wasteful behaviour, even as governments and industry acknowledge that the problem of waste is ‘wicked’, i.e. an intractable problem that resists solution, and itself is a symptom of another problem (Rittel and Webber 1974).

Design has long been implicated as an activity that is inherently waste-making, in service to an economic system requiring continual consumption of virgin resources. A repositioning of waste comes from industrial ecology and for the past fifteen years has been popularised by the Cradle-to-Cradle concept, in which waste becomes ‘food’ for new cycles (McDonough and Braungart 2002). A core concept of ‘Cradle-to-Cradle’ (C2C) is to develop a life cycle for products that emulates the life cycle of nature. McDonough and Braungart propose two streams of materials: ‘biological nutrients’ and ‘technical nutrients’. Biological nutrients are those from natural materials such as wood, plant and animal fibres and materials, manufactured in such a way that they can be composted safely at end of life. ‘Technical nutrients’ include non-biological human-made components such as steel, glass, plastic to be reclaimed at end of life. The item would be disassembled into its basic parts for reuse into new products. Blends of technical and biological materials are known as ‘monstrous hybrids’. Despite the quasi-utopianism of the model in a world crammed full of monstrous hybrids by design, the principles of technical and biological resource streams has become central to the concept of the circular economy.

The concept of the circular economy has its roots in ecological economics and has ‘designing out waste’ as a core principle. A circular economy is “an economic system that replaces the ‘end-of-life’ concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes” (Kirchherr et al 2017, 224). A circular economy is enabled through streaming materials and keeping them in motion as long as possible, inspired by the life cycle thinking of cradle-to-cradle. Consumption must be reduced overall for a circular economy to be a sustainable system. Critically, if the use of a resource increases due to efficiency gains in recycling, then environmental benefits may be lost (Zink et al 2017). It is important to highlight the role of design in enabling and maintaining these resource continuums, as through design it would be possible to conceptualise products that make use of new materials in a smart way, consider easy disassemble and waste streams, and, better yet, create products that can be designed with longer and more varied lifetime in mind. Design theorist Tony Fry (2009) warns of the danger in this for C2C, which may simply promote further unsustainable consumption.

Waste is a system that has multiple stable and dynamic states as describes in the concept of resilience in systems (Folke et al 2010). Although waste can be tackled instrumentally through the classic ‘reduce, reuse, recycle’ heuristic, waste must also be acknowledged as essentially a wicked problem, a symptom of the wider unsustainability of the present world economic and social systems. When waste is positioned as part of a complex system, multiple intervention points are required, in full acknowledgment that they may have unintended consequences. In the next section we examine in further detail the frameworks for representing these interventions to address waste.
3. Frameworks for Representing Waste

3.1 Hierarchical Visualisations

The concept of the ‘waste hierarchy’ has its origins in Earth Day 1970, with the three ‘R’s of reduce, reuse and recycle (Byers 2018). Traditional visualisations of waste management strategies are based on hierarchical representations of the different methods of waste management and recovery, usually graphically represented as a pyramid—a triangle. Triangles often represent moving forward, pointing towards something, conversion of factors or energy, and are the most commonly used shape to represent hierarchy.

Hierarchical representations embed the common notion that what is at the top is more important than what is at the bottom of the diagram. They are linear and represent discrete instances of the system. As usually hierarchies have less instances with more importance and more instances with less importance, the triangle is a natural fit for its representations. If any connections are represented, these are usually connections of power. Figure 1 shows an organisational hierarchy, where each position is connected by relationships of power.

Figure 1 Hierarchical diagram representing organisational structure: more power, less instances on top, less power, more instances at the bottom. Source: (https://www.forbes.com/sites/jacobmorgan/2015/07/06/the-5-types-of-organizational-structures-part-1-the-hierarchy/#e740d1852529)

Waste hierarchies usually represent the waste management outcomes, from most preferred to least preferred option (DEFRA 2011). When visualized, they typically come in two forms:
the first and more common one is an inverted pyramid, with the wider part of the triangle on top representing the most desirable outcomes (avoiding, reducing) and the point of the triangle facing down, representing the least desirable waste outcomes, such as landfill or other types of non-recoverable waste (Figure 2). In these diagrams, the size and position of the shapes are equivalent to the desirable amount of waste for each outcome, making them simple and intuitive to read.

The second type of waste hierarchy uses a pyramid facing up to show the most desirable options as the small triangle up the top. These diagrams move from a representing a desirable state, to showing the actual volume of waste on each layer. For instance, Figure 3 shows “disposal” at the base of the pyramid as the larger area of the triangle, meaning that disposal is the outcome with the most volume, even though it is the least desirable. It also shows “Prevention” at the apex triangle, the smallest structure in the diagram, showing that, even though it is the most desirable, prevention is the outcome with the least uptake. This turns the pyramid into a good awareness tool, but makes it less intuitive to read. On the other hand, positioning the most desirable actions at the apex of the pyramid evokes a sense of something that is meant to be achieved, a top goal.
Triangles are a symbol of power and synergy, and naturally highly hierarchical. Triangles are visually stable when sitting on their base, unsettling when inverted and sitting on its apex. Triangular, hierarchical representations of waste evoke a few interesting instinctive feelings: the graphs that show the most desirable as the larger area on top, is the inverted triangle which evokes feelings of non-stability and physical “impossibility”. The graphs that show a stable triangle are the ones where the large area is at the bottom and represents the least desirable option which holds more volume of waste. This is the graph with the geometric form that is stable and comfortable to us, and shows the apex of the pyramid and something difficult or impossible to achieve, or that would need a certain level of effort.

Analysing the waste hierarchies against the criteria presented in Section 1.3, it becomes clear that hierarchies are general visualisations of waste management outcomes and can be used to represent any waste stream, but is specific to none (criterion 1). They represent discrete states, having minimal or no space to demonstrate fluidity of or between management states and outcomes or synergy between actors on each stance (criterion 3), making this kind of diagram limited to its own hierarchical structure and unable to represent any type of connection or circularity. As it is not visualised, when reading the graphic, users are also not stimulated to think about those connections or circularity of waste.

### 3.2 Circular Visualisations

Circles are the most natural shapes found in nature, and the ones humans are most
comfortable with. Circles are equal, dynamic and closed. They directly evoke the shape of
the planet and its closed nature as a system (no out). As such, circles are frequently used
in multiple kinds of visualisation, especially the ones dealing with the natural environment
or human behaviour. There could be no more appropriate shape to represent systems of
production that leave nothing behind.

Circular representations of waste clearly show fluidity and movement between multiple
states within the system, and are mostly used to represent the life cycle, or journey, of
a certain type of product, material or process. It fits perfectly with the Cradle-to-Cradle
philosophy of waste which mimics nature’s circles of life, demonstrating reuse, recycling, re-
capturing of materials through the process (see Figures 4, 5 and 6).

Figure 4  Example 1 of a circular representation (source: https://www.toronto.ca/services-payments/
recycling-organics-garbage/long-term-waste-strategy/working-toward-a-circular-economy/
In analysis specific to the circular economy, the circular visualisations vividly contrast with the dysfunctionally-linear economy, leading to waste, and the imperfect loops of the ‘reuse’
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economy, in which some waste is recaptured and looped back into the system, while other waste is lost (see Figures 7 and 8). The symmetry and strength of the preferred circular economy, represented by the neat, contained circles adds visual weight to the sense that the circular economy appears to be “intuitively better” (Zink & Geyer 2017). In actuality, the circles are too neat and beguilingly simple.

Figure 7 Examples of dysfunctional linear/reuse/circular representations (source: https://www.govImpacten.nl/topics/circular-economy/from-a-linear-to-a-circular-economy)

Figure 8 Examples of dysfunctional linear/reuse/circular representations (source: Vanburen, et al (2016). https://doi.org/10.3390/su8070647)

Many of the circular representations of waste flows focus on the movement of materials through closed and/or cascading loops of technical and biological materials, respectively. These diagrams visualise the C2C principles either as two closed circles, operating
independently of one another (Figure 9) or with some overlap (Figure 10). These aid in demonstrating the different kinds of interventions required for different kinds of waste streams.

Figure 9  Representation of independently operating circles (source: https://www.government.europa.eu/is-the-uk-doing-enough-on-the-circular-economy/93304/)

Figure 10  Representation of circles operating with some overlap (source: https://biconsortium.eu/news/bic-views-waste-package-successful-circular-economy-requires-vibrant-renewable-bioeconomy)
What the current circular visualisations of waste and economy don’t do well is to represent connections between different players and interventions within the system. Figures 11 and 12 visualise greater complexity of circular economy processes as these examples have biological and technical material streams considered, identifying not closed circles but cascading loops showing many pathways to avoid a material becoming waste. The technical materials stream also incorporates the ‘R’s of the waste hierarchy within it, albeit without privileging one kind of action over another. When this happens it is done by adding extra circles and loops cascading out of the main circle which invariably create graphics that are over-complex and difficult to read (Figures 11 and 12).

**Figure 11** Example 1 of over-complex graphics (source: https://www.creatingvalue.net.au/circular-economy-defined/ Date accessed: 6 November 2018)
Circular representations of waste are frequently used to represent multiple waste streams, sometimes on the same graphics (WVEAC, criterion 1), and are able to demonstrate the role of different disciplines within these cycles (criterion 2), but they fail to represent connections between the multiple actions and disciplines (criterion 3). When these are attempted, it usually breaks the circularity and produces a highly complex diagram.

The danger of the circular representations of economy is the fact that for them to represent true circularity—which usually involves multiple aspects of a complex system—the graphics require a level of complexity that makes them difficult to read, follow, understand and apply to a real-world situation. This defeats the core purpose of visual representations which is to communicate ideas more clearly, more accurately and efficiently.

To try to represent their own cycles in more efficient ways, industry and businesses tend to simplify the circular representation usually showing only one aspect of the system, and sometimes claiming circularity where the circularity does not really exist. Figure 7, for example, represents a reuse economy (Figure 7), or an economy with feedback loops (Figure 8) using a circular visualisation and ignoring the processes that happen beyond the main circle. The problem with not addressing those open loops is that as they are not visualised, they are seen as external to the system and not part of the problem. Similar to what we do with our household waste, the open-ends and unwanted ideas are sent to the outside of the main circles and can be ignored because they are not really our problem anymore. By
representing those open-ended pathways, it makes them part of the problem and therefore considered into strategic and decision-making processes.

What we need today more than ever is a form of visualisation that captures the multiple expertise necessary to understand and intervene in the waste system in an integrated way. Both hierarchical and circular representations are one-dimensional and usually represent discrete units, interventions or states, as such, they are not able to represent the complex systemic interrelations of the systems around waste and the multiple level interventions.

The visualisation proposed in this paper was born from the need and desire to capture transdisciplinary synergy across multiple states of waste. In a way, we sought to combine the positive aspects of hierarchical visualisations with those of circular visualisations of waste, adding space for capturing interaction between actors and outcomes, as such adding the potential to perceive the dynamics and flows between states of the matter.

4. Designing the Waste Rainbow

Rainbows are optical illusions generated by the combination of three different light phenomena: refraction, dispersion and reflection. When light touches a surface, it is changed by that surface in different ways: some of it can be absorbed by the surface (and transformed into another type of energy), some of which is reflected back to the origin, and some of it might go through the surface, in this case, the angle in which the light hit is usually different from the angle it will have within or through that surface (refraction). In a rainbow situation, the light hits droplets of water in the air and is refracted into a different angle in a way that its wave-lengths become dispersed, showing the multiple colours within white light. These are then reflected out of the droplet, generating on the human viewers, an optical illusion of a 7-colour arch in the sky.

Surprisingly similarly to rainbows, waste also suffers refraction, dispersion and reflection. We create the refraction—the change in angle, change in state of matter—when we make the decision that a certain product is not useful anymore and should go to ‘the bin’. Once waste hits that state, it can be dispersed into multiple waste streams that each have their own characteristics and effects. This dispersion can start in our own houses or the places where the product is consumed, and usually finishes at the MRFs. The part that we often do not realise is that waste is always reflected back to us in one way or another.

The Waste Rainbow was designed with the intention to capture these aspects, as well as the ideas of fluidity, continuum and complexity. What triggered its creation was the authentic need to represent the synergies of transdisciplinary works done in the QUT Centre for a Waste Free World, revealed through team discussions and workshops where the researchers experimented with multiple ways to represent all their active projects and interventions to see how they relate and can work together. What follows is an account of how the authors, together with colleagues came up with the rainbow analogy as a canvas to plot and visualize connections amongst interventions within the waste system.
During the initial stages of working together and setting up the new Centre, the first step was to map existing waste research occurring at QUT. Colleagues worked in building and construction waste, food and organic waste, agricultural waste, e-waste, textile waste, and plastic waste, and came from multiple disciplines such as business, robotics, polymer sciences, law and design. With colleagues, we held a series of workshops to collaboratively formulate our waste research. Initially the organisation of the projects and interventions was done via waste stream (e.g. e-waste, food waste, construction waste, plastic waste, textile waste), but it was soon clear that we needed a more flexible structure that allowed for the multi-streams and “in-betweens” to be captured.

Turning back to Douglas, we framed waste as not a fixed state of matter, but a state that matter passes in and out of as humans ascribe value to it. Immediately, this suggested an approach. Waste is the state to avoid, hence there is a ‘pre-waste’ state, before matter becomes waste, and a ‘post-waste’ state, after matter has been delineated as waste. This in turn suggested a spectrum, just as the pyramid suggests a hierarchy (Figure 13).

From this process, it was clear that a “canvas” for plotting these synergies was needed, and the spectral representation of the rainbow came as a natural fit for the Centre’s philosophy of waste as it shows no discrete states, naturally representing the fluidity of matter. In order to move away from the ‘waste’ state in the centre, there are a range of interventions. In the pre-waste state, the interventions are drawn from the traditional waste hierarchy including prevention, reuse, repair, re-purpose and remanufacturing. In the post-waste state, interventions include recycling, conversion processes, and then new products. We indicate these interventions on the Waste Rainbow (Figure 13).
As the traditional waste hierarchy demonstrates, there are preferred approaches to managing waste, with prevention higher. Although in designing the Waste Rainbow we have avoided the hierarchical model, through the choice of warmer colours on the right, we have symbolically captured the fact that greater energy is required to transform material from the state of ‘waste’ into the state of ‘post waste’. The benefit of the canvas format is that it offers space for representation of multiple layers of intervention which can be shown separately or in combination. It also allows for any type of connections between those interventions to be represented within and throughout the multiple states of waste.

5. Using the Waste Rainbow

Since developing the Waste Rainbow, with our collaborators we have used it in a number of different ways. Most usefully, it has been a means to structure a philosophy of working together to address waste in which multiple expertise, approaches and perspectives are needed. The word “philosophy” is used here as the Waste Rainbow is the synthesis of a collection of theories and attitudes towards waste that defines the research approaches and values of this group of researchers.

As well as using the Waste Rainbow as representation of our philosophy for working together, we also use it as a means to plot individual projects, visually indicating the part they play in addressing waste (Figure 14). Rather than a hierarchical positioning of interventions, which inevitably implies that some interventions are more impactful than others, our rainbow demonstrates all interventions are needed in working towards the desired goal.

![Figure 14: The Waste Rainbow to mark point of intervention](image)

With our colleagues we used the Waste Rainbow as a practical way to capture and sort the varied expertise and projects happening across the university. An example is provided in Figure 15 with our mapping of ‘expertise’ and two waste streams, plastics and textiles. With our team we have used it to map research across nine additional waste streams. Using the Waste Rainbow concept as a table was an efficient way to capture and organise diverse research and community engagement projects happening across multiple disciplines and faculties. Importantly, the gaps suggest opportunities, it helped identify where further expertise is needed—whether from our own institution, or in collaboration with other
institutions—; how existing expertise applied to one waste stream can be potentially applied to another; etc. In this way the Waste Rainbow revealed synergies and opportunities that were invisible before being plotted.

| Expertise | Prevention | Repair | Reuse | Remanufacturing | Waste | Recycling | Conversion processes | Post-Waste |
|-----------|------------|-------|-------|------------------|-------|-----------|--------------------|------------|
| Plastic   | Behavioural economics, marketing, design, law | Design and creative practice | Law and policy analysis | process engineering, economics of processes, robotics | Industrial biotechnology, transproducts and bioengineering | Advanced materials |
| Textiles  | Student project 1 - design, law | Creative practice group - repair and making workshops - design | Community + student engagement project 1 - design | Creative practice project 1-3, design | Research project 1 - robotics, law & design | Research project 2 - engineering, design, chemistry | Commercial partner - research project 2 |

**Figure 15** Example of mapping research and community engagement projects using the waste rainbow

To provide an example, the mapping of the textile waste area, showcased activities happening in the community engagement space around creative reuse and maker space activities using waste fabric. These workshop activities were also applied to use plastic waste at a university-wide Waste Maker Day. Expertise in industrial biotechnology applied to a textiles research project opened up broader discussions with colleagues in polymer chemistry which in turn led to discussions and potential projects around bio-degradability and compostability. The Waste Rainbow has made visible some potential connections that would otherwise be missed without the visualization process. The aim is to create an organic web of activities that draws upon the Centre’s expertise and contributes to a more circular and less wasteful materials streams through a coordinated mélange of design, science and behavioural approaches.

### 6. Conclusion

Visualising the complexity of waste is no easy task, and the challenges presented defined the several advantages to our approach. First, it provides a holistic view that privileges prevention as much as recycling and continued material circulation. Second, using the Waste Rainbow can help expose gaps in the research agenda, and can also provide an inclusive view of where different kinds of expertise are required. Third, it shows connections between the interventions, and visually signifies how interventions at one point of the system might interfere with actions happening at the other end.
Nonetheless, a weakness of the Waste Rainbow is its apparent linearity. Looping, circling, and so on are expected in the circular economy agenda. Although this is a visual limitation of the Waste Rainbow, in its simplicity it may be of most use. In future iterations, it could be visualised as a cylinder, joining both ends. Similarly, it could be designed as a three-dimensional surface with ‘waste’ as the valley in the centre, in line with resilience theories where stable states act as attractors (Folke et al 2010, Gunderson and Holling, 2002, Walker et al 2004). If material reaches this valley, more energy is required in the states on either side, whether to ‘pull’ material up before it becomes waste, or to ‘push’ it up out of the waste valley. Mirroring the concept of ‘panarchy’ (Holling 2001), the Waste Rainbow can be complementary to other visualisations, and ultimately become a synthesis of those, by representing hierarchy into a dynamic system of multiple cycles.

By all means the Waste Rainbow is not definitive, it’s apparent simplicity might mistakenly lead users to see the waste system as a simple and direct arena, which is far from the truth. However, some abstraction from the incredibly complex waste system need to be taken in order for researchers and practitioners to make sense of the issues and position themselves as actors and collaborators. In that sense, the Waste Rainbow is a valuable tool to initiate discussions, map interventions and represent a well-defined philosophy around waste research and practices.

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7. References
Byers, A. (2018). Reuse It: The History of Modern Recycling. Cavendish Square.
DEFRA. (2011). Guidance on Applying the Waste Hierarchy. Accessed February 15, 2015. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/69403/pb13530-waste-hierarchy-guidance.pdf
Douglas, M. (1984 [1966]). Purity and Danger. Ark.
Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience Thinking: Integrating Resilience, Adaptability and Transformability. Ecology and Society, 15(4). doi:10.5751/ES-03610-150420
Fry, T. (2009). Design futuring: Sustainability, ethics and new practice. University of New South Wales Press.
Gunderson, L., & Holling, C. S. (Eds.). (2002). Panarchy: Understanding Transformations in Human and Natural Systems. Washington DC: Island Press.
Hauser, S. (2002). “Waste into heritage.” In Waste-site stories: The recycling of memory, edited by Brian Neville and Johanne Villeneuve, 39-54. State University of New York Press.
Holling, C. S. (2001). Understanding the complexity of economic, ecological, and social systems. Ecosystems, 4(5), 390-405. doi:http://dx.doi.org/10.1007/s10021-001-0101-5
Humes, E. (2012). Garbology: our dirty love affair with trash. New York: Penguin Group.
Kirchherr, J., Reike, D., & Hekkert, M. (2017). Conceptualizing the circular economy: An analysis of 114 definitions. Resources, Conservation & Recycling, 127, 221–232. https://doi.org/10.1016/j.resconrec.2017.09.005
Moser, W. (2002). The Acculturation of Waste. In Waste-Site Stories: The Recycling of Memory, edited by Brian Neville and Johanne Villeneuve, 85–106. State University of New York Press.
McDonough, W. and M. Braungart. (2002). Cradle to cradle: remaking the way we make things. North Point Press.
Packard, V. (1960). The Waste Makers: Ig Publishing.
Rittel, H. and M. M. Webber. (1974). Wicked problems. In Man-made futures: Readings in society, technology and design, edited by Nigel Cross, David Elliot and Robin Roy, 179-197. Hutchinson Educational and Open University.
Scanlan, J. (2005). On Garbage. Reaktion Books.
Strasser, S. (2000). Waste and want: a social history of trash (1 ed.). New York: Holt Paperback.
Walker, B., Holling, C. S., Carpenter, S. R., & Kinzig, A. (2004). Resilience, adaptability and transformability in social–ecological systems. Ecology and Society, 9(2). doi:https://doi.org/10.5751/ES-00650-090205
Zink, T., & Geyer, R. (2017). Circular Economy Rebound. Journal of Industrial Ecology, 21(3), 593–602. https://doi.org/10.1111/jiec.12545.

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