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Conceptualising the Technosphere of a Circular Economy Through a Living Systems Metaphor

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Abstract. This paper explores the move to a circular economy through the metaphor of a living system: a forest. The technosphere of a circular economy is an entirely human-made and managed realm. This research aims to explore how a common understanding of how a forest works can be used to conceptualise the products, components and materials that circulate in the technosphere as "fruit". This exploration entails four aspects of the metaphor: (1) the recipient needs to know what it is "eating", (2) the fruit needs to be "non-toxic" for the recipient, (3) the fruit needs to be nutritious and, (4) the wider system needs to be able to "metabolise the nutrients". This metaphor allows for a more interconnected and holistic understanding of different economic and societal actors, their relationships and overall productivity.

The nature of many materials in the technosphere prompts consideration of issues of standardisation, complexity, disclosure, and liability together with intellectual property rights. However, special attention and/or treatment is needed for materials that can be considered "substances of concern", which ideally would be designed out or carefully managed to avoid exposure. Furthermore, the paper explores the "nutritional value" of technosphere materials, emphasising the need for increased product longevity, through strategies such as design for disassembly and the right to repair. Finally, to allow the wider, open system to benefit from diverse inputs, it requires further decentralisation of supply chains, enabling accessibility of inputs to more informal or smaller-scale economic entities and fostering local creativity. To support this change, concepts related to nutrient stock maintenance and total product liability are addressed.

Keywords: CONCEPTUAL METAPHOR · ECOLINGUISTICS · TECHNOSPHERE · CIRCULAR PRODUCT DESIGN

1 Introduction

It was the American author Wendell Berry who said: *"We don't have a right to ask whether we're going to succeed or not. The only question we have a right to ask is: what's the right thing to do? What does this earth require of us if we want to continue to live on it?"* It is a plea for an enquiry into different ways of thinking, acting, and driving change.

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One way to do so is by exploring new ways of thinking through conceptual metaphors. Research in cognitive science by Lakoff & Johnson (1980) posits the core role of conceptual metaphor in all our abstract thinking. It can affect how we think of abstract ideas, such as the economy, but also what kind of solutions we come up with (and what we do not think of).

Within the discourse of circular economy, it is the machine metaphor that currently dominates (Fromberg et al., 2023a). This metaphor emphasises material flows as inputs and outputs of the economy through the logic of pipeworks. The consequences of this metaphor are an emphasis on resource inputs and outputs and a lack of attention to the social implications (Mutari, 2018). This same metaphor is used frequently in current economic discourse and therefore any putative circular economy has the potential to repeat the same patterns of thought as the current unsustainable economy (Fromberg et al., 2023b). This paper will follow the implications of a radically different, living systems metaphor to explore a subdomain of a circular economy: the technosphere. This refers to products, materials and components where order is rebuilt by human intention and facility rather than natural ecosystems (Braungart & McDonough, 2002). The purpose of doing this is to explore new lines of enquiry that might challenge the status quo and provide a critical reflection on current discourse.

2 A Living Systems Metaphor: The Forest

As Tate et al. (2019) explore in their work, the forest metaphor has been indicated as an insightful line of enquiry in circular economy discourse. Within this metaphor (elaborated upon in Table 1), the economy is conceptualised as the "forest floor" on which the economic actors are seen as "creatures" on the forest floor such as scavengers or decomposers (Tate et al., 2019).

In addition to this, through this metaphor, products, components, and materials could be conceptualised as "fruit", released by businesses, conceptualised as "fruit trees". This sub-metaphor will be the scope of this paper.

Biological materials that can be composted and given back to the soil, may lend themselves better to the forest metaphor since it is more than just a metaphor in this case. However, this paper will outline the logic of the more challenging TECHNOSPHERE PRODUCTS, COMPONENTS AND MATERIALS AS FRUIT. This consists of materials that are configured, unlike biological materials in natural ecosystems, and therefore present unique challenges. In the work of Cradle to Cradle, the question of configuration revolves around how order is rebuilt. In the 'technosphere', it is by human intention and facility rather than natural ecosystems (Braungart & McDonough, 2002).

The existing technosphere often intends to operate like a closed system, especially in cases where ownership remains at the Original Equipment Manufacturer. Through business models where the performance of or access to the product is sold to the customer, businesses act like a stand of trees, asking for their fruits back after they drop them.

This closed systems approach may be suitable for certain products that, for example, require specialist tools for maintenance or where user involvement could pose a safety risk. Where a closed system is not a necessity, the forest metaphor uncovers the potential of open systems for this domain. Therefore, some of the features of this metaphor that will be explored in this paper are:

Table 1. Comparison of roles between natural networks and the business ecosystem by Tate et al. (2019)

Role	Natural networks	Business Ecosystem
Producer: take sunlight and use the energy to make sugar	Any kind of green plant	Mining (primary); manufacturing (secondary)
Consumer: Feed on producers or other consumers to survive	Predator animals	Wholesalers (primary); retail (secondary); end customer (tertiary)
Scavenger: Contribute to the decomposition by breaking them into small pieces of organic material	Animals feeding on dead animals or dead plant matter	Dismantling, sorting, and transportation of used materials
Decomposer: Release the organic and inorganic molecules in the form of nutrients for the plants and animals	Bacteria and fungi	Transformation of used materials back into the system

- The recipient needs to know what it is "eating".
- The fruit needs to be "non-toxic" for the recipient.
- The fruit needs to be nutritious.
- The wider system needs to be able to "metabolise the nutrients" too.

3 The Recipient Needs to Know What It Is "Eating"

Fruits are often released by fruit trees to be consumed by other entities so that the seed can be released and fertilised in a different place. They have two main functions: to protect the seed and to support the dispersal. Bright colours indicate a ripe fruit, ready to be released.

Animals such as birds or mammals observe the fruit and have a bite. However, not everything that eats fruit is beneficial for the tree and, therefore, some fruits contain a defence mechanism that prevents certain entities from consuming them. After the first look, the first bite gives the animals additional sensory information (smell, taste and texture) that indicates whether they expect this fruit to be good and safe for them to consume.

Answering the question of whether something is good and safe for use, can be a challenge for technosphere materials. Not because these will necessarily harm the one that initially uses it, but because of the complexity of the ingredients. The technosphere offers a vast array of different materials. Many products within the technosphere can be considered an "omelette" of materials – often challenging to deconstruct back into constituent elements. A smartphone can typically comprise 257 different parts (metallic and non-metallic) (Singh et al., 2018). These materials cannot flow as freely as the nutrients of natural systems if it is not exactly clear what it is – especially after the product has been used. When certain contents enter material streams (such as copper

in aluminium alloy streams), contamination can happen which possibly degenerates the functional or structural aspects of material stocks (Syberg et al., 2022). This is ultimately where the harm may occur through the degeneration and contamination of material stocks. To allow for appropriate identification of these technosphere products, components, and materials, transparency and traceability must exist at every phase.

Standardisation of the palette of materials that are used for products that contain technosphere materials would make it easier for the system to act like nature and prevent the degeneration of material flows. However, this is not always realistic because there are functionality and performance reasons for the diversity of material configurations (Anastasiades et al., 2021). Composites in the technosphere bring other challenges on top of this variety in that they might be difficult or operationally impossible to disentangle. Therefore, the disclosure of the exact ingredients of these products – a materials or product passport - can allow different entities to make an informed decision about whether to use the materials or not (Adisorn et al., 2021).

Arguments against disclosure of materials ingredients emphasise the role of intellectual property rights (IPR) - this is no surprise since 30% of global value is mostly attributed to IPR and goes together with an increase in applications for patents worldwide (World Intellectual Property Indicators, 2022).

Product passporting through public blockchains could support the disclosure of crucial information about the material's ingredients with some protection for the information that is considered intellectual property by the business (Kouhizadeh et al., 2020).

However, such a system would only truly work when it is openly accessible to all entities in the ecosystem. This would allow not just "the big trees" (businesses and the formal economy) to use the nutrition that is contained in its "fruit" (materials) but also "scavengers" (informal, smaller-scale initiatives) and "decomposers" (recycling facilities) to fully access all information that they need to ultimately understand whether the input is beneficial.

4 The Fruit Needs to Be "Non-toxic" for the Recipient

Poisons found in fruits are often specifically designed to make sure that some specific hungry entities back off and leave enough for the right ones to eat. Some fruits that are safe for consumption by, for example, birds, can be unsafe for consumption by other, specifically targeted animals, microbes and fungi. Where trees pick their "customers" and use poisons to repel the unwelcome ones, the technosphere contains toxins or substances of concern. These are usually part of materials and chemicals to achieve a certain effect (for example: functionally or aesthetically). The toxicity can be considered an unintended consequence of these choices.

Examples of such substances of concern are fire retardants, endocrine disruptors and the family of PFAS materials (CHEMtrust, 2023). Especially unnecessary substances of concern, such as BPA, need to be designed out to avoid exposure and contamination of material flows. This also applies to "forever-chemicals": a group of approximately 9000 materials that do not naturally break down in the environment (Buttle et al., 2023).

To allow for products, components, and materials to be safe by design, substances of concern must be designed out of the product as well as the value chain. It is important

that first the substances of concern are identified not only in the final product but also within the value chain. Often, in the manufacturing and production process chemicals are used to create a desired outcome. There is therefore a potential to create waste and pollution at this stage as well, with the potential to damage the ecosystemic health of the environment surrounding the factory and beyond (Lyu et al., 2021).

However, when these substances cannot be designed out, they need to be managed through a closed pipework system where they are kept in isolation from substances that are not harmful (Beekman et al., 2020). Therefore, it would be useful to conceptualise this domain through a different metaphor instead. For example, a machine metaphor where the focus lies on managing a closed system through the control of inputs and outputs (Braungart & McDonough, 2002). During the use phase, it is important that the exposure of the substances of concern to the user is minimised and that there is a duty of care of the manufacturer to collect and manage the product at the end of life.

5 The Fruit Needs to Be Nutritious

When safe for consumption by a recipient, some fruits may be more nutritious and richer in vitamins and antioxidants than others. After eating these nutritious fruits, they can cause a range of benefits for a variety of biological processes which can be seen as value that is derived from the fruit. In the technosphere, this value can be seen as the utility or value of the products, components and materials that go around.

To allow products, components, and materials to deliver a high value, they need to have an increased utilisation. Products in the technosphere have the most value (compared to materials and components) and therefore product longevity is the most effective way of retaining the highest value (Den Hollander, 2018). After keeping the product utilised for as long as possible, the inertia principle (Stahel, 2010) can be followed to allow the retention of as much value as possible, as elaborated upon in Fig. 1.

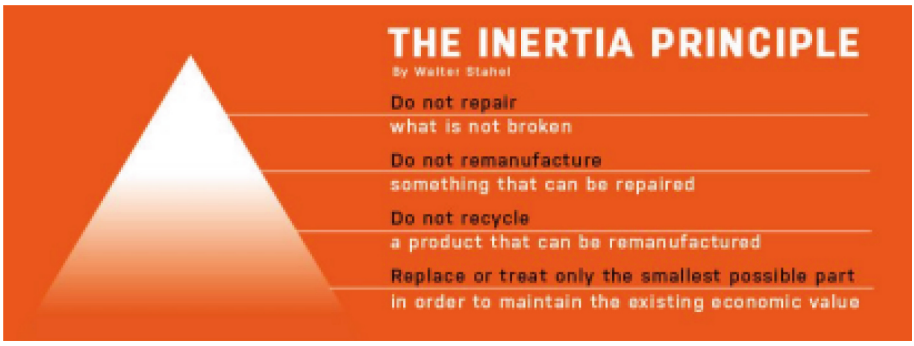


Fig. 1. The inertia principle is a concept by Walter Stahel (2010), illustration above is designed by Yvo Zijlstra

Sometimes value can be identified in the technosphere, but it is inaccessible. An example can be found in the recycling of jeans - which ideally happens after this product has cascaded through all previous possible lifespans. When jeans arrive

at a recycling facility, one of the first things that tends to happen is that they cut the top of the jeans off: the part that contains the button, zipper and rivets. This is being done because it takes too long to remove these manually and therefore this part of the jeans is considered waste. The problem here is a lack of convenient access, making it more likely for that value to be lost.

The right-to-repair movement sparked many conversations around design for disassembly, which would help mitigate many accessibility issues. The movement focuses on *"supporting people's freedom to repair and customise their gadgets, such as smartphones. To make diagnostic tools, repair manuals, and replacement parts available to the public, the movement continues to push for laws requiring manufacturers to do so."* (Ozturkcan, 2023; p. 1). Convenient access is an important enabler for increased utilisation and product longevity but does not stop at designing for disassembly. To allow customers to have genuine agency over the product, this also means access to blueprints of components to repair, customise and upgrade.

The inertia principle comes back to increased longevity which requires a change in the "sell more, sell faster" mentality of some businesses and allows for productivity to slow down so that all that has been produced can be utilised appropriately first.

6 The Wider System Needs to Be Able to "Metabolise the Nutrients"

The fruit has an important value to deliver after the initial consumption and digestion: fertilisation of the area where the seed will settle. Important nutrients are delivered together with the seed to ensure the right conditions for new life to thrive. These nutrients do not necessarily have to be used by the seed but are available to other entities in the ecosystem as well: it is an open system. Open systems allow nutrients to flow freely and be of use to a variety of entities in the wider ecosystem.

To allow the wider system to benefit from products, components and materials that are available, these should be able to be utilised independently and without the need to ask for consent or approval from an external party.

When products, components and materials become accessible to use independently from the Original Equipment Manufacturer, a wealth of creativity could be unleashed on a more local and distributed level. For example, through repair cafes, makes spaces, tool libraries and other more decentralised manufacturing capabilities, more informal economies can thrive on these stocks. In open systems, nutrients may end up in a place where they are not needed. In nature, fungi fulfil an important role in the redistribution of these, which they do in return for sugars from photosynthesisers (Mason-Jones et al., 2022). This possibility for redistribution is an important feature that could enhance accessibility. A similar function needs to be developed in a circular economy, where nutrients can go where they are needed to fulfil crucial functions.

These are comparable with the so-called "gap exploiters" in the technosphere, which are often small-scale economic entities that recognise opportunities that others tend to overlook. They utilise and redistribute the leftover value of products, components, and materials. In addition to this, they often see opportunities in unsold goods or reinvigorate the value of "old" products by turning them into different objects where they can deliver more value (Bakker et al., 2014). Therefore, the importance of "gap exploiters" may

increase with more open systems. Nevertheless, the build-up of certain resources may still happen leading to a stock that is not fully in use. Some cycles in the forest may take many years to be converted. This slow pace of conversion in the technosphere could be due to resource-efficient technologies, changing demands and population shrinkage, for example. When products, components and materials become available for use in the system, they may not immediately be utilised.

It may require some time to build up a community of "decomposers" (Tate et al. 2019) around materials that are abundant in certain areas. This may lead to the increased need for appropriate storage (and maintenance if necessary) (Mao et al., 2018) for, in some cases, extended periods. This might look like under-utilisation or inefficiency of materials. However, redundancy has an important role to play in resilience, ultimately contributing to the health of the wider ecosystem (Fath et al., 2019).

The introduction of the notion of Total Product Liability (Webster, 2021) may incentivise participation in this system because manufacturers will be held responsible for the recovery of their products, components and materials. This does not mean that manufacturers will act as trees, asking for their fruits back, but rather if the contents of their fruits are not useful (or even harmful) for other entities in the ecosystem, they will be penalised for dispersing them in the first place.

7 Conclusion

This paper explores the implications of applying a living systems metaphor, the forest, to the technosphere by reimagining products, components and materials as "fruit from a tree". Unlike the currently dominant metaphor of a machine, which conceptualises the economy as a closed system of controlled inputs and outputs, the forest metaphor suggests an open flow of resources and information. Treating materials in the technosphere as 'fruit' is not a trivial task and requires profound changes such as restrictions to intellectual property rights and the adoption of transparent practices that, for example, disclose material ingredients, blueprints and other essential data. In an open nutrient system, these elements must circulate freely to support the diverse needs of multiple actors within the wider circular economy.

Designing technosphere products as "fruit from a tree" has implications for how these products are conceived, developed and used. Designers should not only focus on introducing new "nutrients" that can be repurposed across various configurations, but also on utilising local and abundant resources to meet production needs. This approach requires a new way of thinking, where design goes beyond simply serving the end user and instead considers the needs and contributions of all entities involved in the value chain, from production to disposal and reuse. By celebrating local resources and capabilities, designers can foster more resilient and self-sufficient communities, reducing the dependency on global supply chains and promoting a place-based circular economy. Ultimately, adopting this metaphor may challenge designers to reframe their role from creators of isolated objectives to contributors to a dynamic, interdependent ecosystem of economic activity.

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