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The Waste-Resource Paradox: Practical dilemmas and societal implications in the transition to a circular economy

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ABSTRACT

The European Union has vowed to transition from a linear to a circular economy (CE). Many innovations, new business models, and policies have begun to emerge to support the push for further institutionalizing CE practices. A large portion of these attempts are based on transforming a flow currently labeled as a waste stream into a value proposition, i.e. a resource. However, this ironically increases the risk of creating a demand for these waste streams, which thereby may become commodified. In this article, we unpack the inherent dilemmas and implications created by this phenomenon, which we define as the Waste-Resource Paradox (WRP). Understanding the WRP is highly relevant, as its manifestation may lead to situations in which the further establishment of "circular" practices may reinforce linear economy by sustaining a waste (over)production in the system or causing undesired social or environmental repercussions. This can tighten a lock-in of the existing linear structures counteractive to CE that have not been explicitly identified or explored to date. We observed that the WRP may evolve and morph throughout time, across boundaries or respective to different societal sectors. Based on our findings, we highlight the profound implications of the WRP for the future of circularity and the potential consequences for a transition to CE.

1. Introduction: Circular economy in Europe

As a society, we are producing increasing amounts of waste, exceeding the earth's capacity for regeneration and natural resilience (Steffen et al., 2015). In 2018, the total waste generated in the 27 European Union (EU) member states by all economic activities and households amounted to over 23 million tons (Eurostat, 2020). Furthermore, the global annual waste generation is projected to increase by 70% by 2050 (World Bank, 2018). It is therefore widely posited that we are in desperate need of a substantial reduction of these wastes. One way to conceptualize such a seminal waste reduction is by envisioning a transition from a linear to a circular economy. The circular economy (CE) has become a central concept used in academia, policy, and industry, defined by its aim to gradually decouple economic activity from the extraction and consumption of finite resources and to design waste out of the systems (Korhonen et al., 2018; Kirchherr et al., 2017; Ellen McArthur Foundation, 2020).

Within the EU context, the European Green Deal launched a strategy to scale up the CE from a pioneering niche to the mainstream economic players, with the aim of making a significant contribution to achieving climate neutrality by 2050 and decoupling economic growth from resource use (European Commission 2019, p. 2). To fulfill this ambition, the EU needs to accelerate the transition towards a regenerative growth model that gives back to the planet more than it takes, advances towards keeping its resource consumption within planetary boundaries, and reduces its consumption respectively in the coming decade. Accordingly, this transition to a sustainable economic system has been included as an indispensable part of the new EU industrial strategy (European Commission, 2020). With such a time-pressing policy goals at hand, the urgency to take action is clear.

However, despite continuous research efforts for decades and several defined policy targets, the circular economy remains a contested and often fuzzy idea, which lacks further operationalization. The existing linear economic model persists as the dominant way of organizing economic activities. In response, many innovators have focused their efforts on circular innovations, in an attempt to slow the mass production of waste per year – basing

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their business model on the use of a waste from another (production) process as an input to their own, thereby "closing a loop".

These innovators may have good intentions and offer promising solutions for some materials; however, some efforts may lead to stabilization or increases in waste amounts, when considering the further commodification of these. The latter can be described as a *rebound effect*: when the environmental benefits created by an innovation are mitigated or outweighed by secondary effects. That is, efficiency gains – e.g. in terms of reduced environmental impact – are lost because of an increase in demand for and use of the respective product or material (Zink and Geyer 2017; Gillingham et al., 2016; Berkhout et al., 2000). Furthermore, rising prices for waste may then also threaten the economic feasibility of certain innovation models or demand for adjustments in business models predicated on free or cheap waste as an input.

In research on sustainability transitions (Köhler et al., 2019; Loorbach et al., 2017), this is referred to as path-dependency and lock-in: the inclination of societal actors embedded within societal regimes towards making the existing material and waste generate "less bad" (i.e. optimizing). Governments designing circularity-oriented policies, as a typical regime actor in this context, use innovation policy and market instruments to incentivize businesses, industries, and consumers to increase efficiency and reduce waste and emissions, while supporting economic growth. Despite governments and policy embracing the transition to circular economy – like the Dutch government's ambition to have a full transition to a circular economy by 2050 ambition (Ministry of General Affairs, 2020), it is not straightforward that we will see a transition towards radically lower levels of resource extraction, consumption, waste, and emissions. A more likely result might be a shift towards improved recycling, loop closing, and a suboptimal transition in the waste industry from landfill and incineration towards material reuse and downcycling (PBL Netherlands Environmental Assessment Agency, 2020), instead of to a circular economy. Still, such incremental changes in end of life waste treatments run the risk of clearly missing the ambitious decoupling targets.

Given the ecological degradation (IPBES et al., 2019), resource geopolitics (Global Harvest Initiative, 2018), and mounting societal pressures, it is also likely that it will be increasingly difficult and costly to achieve further improvements. Still, alternative technologies, new business models and (niche) lifestyles are emerging that can become stepping stones towards future economic models based on "sustainable" circularity, with the lowest possible environmental footprint and the highest possible ecological, social, and economic value creation. On the longer term, such a transition will include deep institutional (economic, legal, behavioral) and infrastructural changes.

In a transition, it is highly uncertain how a system shift takes place, but it inevitably emerges out of friction between new elements and incumbent elements: resulting in destabilization of the current regime (Loorbach et al., 2017). During such a transition process, there is a period in which elements of the existing system remain, but previously experimental innovations begin to further institutionalize. The incumbent structure – the regime – begins to become challenged by alternative methods and models – niches – which may weaken the regime's initial airtightness (Geels and Schot, 2007). This destabilization of the current regime and emergence of niche alternatives results in a "transition zone" of change dynamics (Loorbach et al., 2020). In the transition zone from a linear to a circular economy context, the clash and frictions between the niche and regime elements bring about the phenomenon we analyze here: the Waste-Resource Paradox (WRP). Unpacking the dynamics and implications of the WRP creates awareness about risks and tradeoffs in the steps taken towards an intended transition to a circular economy.

2. Conceptualizing the circular economy and the WRP

To come to a common understanding on what it means to be "circular," it is of value to revisit what is the essence of a circular economy. As is indicated by a meta-analysis of circular economy definitions (Kirchherr et al., 2017), the foundation of CE is built on:

1. The least possible extraction of virgin material from the earth,
2. Energy efficiency towards a low-carbon economy,
3. Economic prosperity, and

2.1. Social equity for current and future generations

Thus, "circular innovations" that base a business model on the consumption of waste are not fully contributing to a circular economy *unless they contribute to the lessening of the virgin material extraction from the earth*. If the same amount of production continues, the innovation that closes a loop does not actually make the system become less extractive – there is just more "stuff" held up in the system stock. This is why a systems approach must be taken to appreciate the full picture and to analyze the WRP within the CE through a transition perspective.

In its broadest sense, the WRP is the paradox that a certain material at any time could be considered a waste or a resource: depending on the perspective of the handlers, the practicality of its use at the end of life, the cultural and geographical context surrounding it, and the legal backdrop on which is it evaluated. The material output at the end of a production process or life cycle is not inherently either a waste or a resource, and it is not determined fully by the material label, physical value, or utilization potential. Its label and perceived monetary value often depend entirely on who is setting the rules of the market game and what the dominant party (e.g. the government, a company manager, a contract broker) defines the standards and prices of materials to be. This complexity and the related system dynamics are illustrated in Fig. 1:

While there has been much attention and research devoted to the acceleration of circular economy, there were no studies our team could find that addressed the particular phenomenon of when a circular innovation might actually reinforce a linear economy. Some literature has touched to some extent on similar matters; for example, Camacho-Otero et al. (2018)'s literature review showed that most existing scientific work on circular models and consumption focused on identifying factors that drive or hinder the consumption of circular solutions, and shares the skepticism of our paper concerning what constitutes a circular business model. Ghisellini et al. (2016)\ argue that the EU's main policy focus is on promoting efficient and effective waste management, aiming at improving recycling rates in Europe, supporting one of the assumptions this paper is based upon. However, no studies were found that criticize or offer insights into what policies may mistakenly be considered circular while long-term impact could have undesired consequences. Zink and Geyer (2017) assert that sustaining the loops of production and consumption in the economy by keeping materials in the economy for as long as possible may create issues: there is a cap on material circulation, and the possibility of rebound effects is a real threat. Lastly, Andersen (2007) states that the extra cost of improving and refining a circular material flow will inevitably reach a point where the cost exceeds the corresponding benefits to society. While all of these studies relate to our observed phenomenon of the Waste-Resource Paradox, it has not been fully conceptualized to date.

In this paper, we further unpack the notion of the WRP to

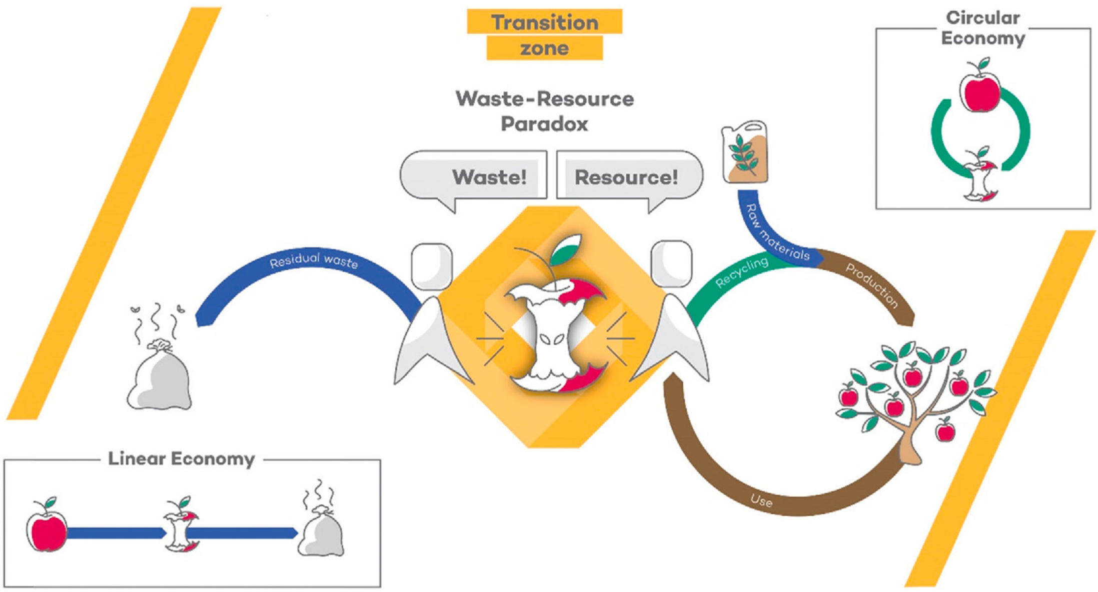

Fig. 1. Emergence of the Waste-Resource Paradox in the "transition zone".

illustrate the large-scale importance and consequences for transitioning to a circular economy. To prevent an unintentional and undesired reversion to an enhanced lock-in of linear economy (under the guise of circularity), it is important to expose unintended implications of closing loops and of the subjective labeling of a material as a waste or resource without premeditated consideration of the resulting ramifications. The WRP raises this question of whether circular innovations are truly contributing to progress towards a CE, and what further implications this has on a national or global scale for a just transition. Through our conceptual lens of the WRP, we examined materials and whether they were defined as resources or as waste. We observed that this had material, energy, economic, and social implications. These are the four dimensions around which we frame this research following these guiding research questions: *What are the systemic dynamics at play and the societal implications of the Waste-Resource Paradox, and how can the WRP help explore dilemmas for (circular) business and policy?*

3. Methodological approach

To test and explore the implications of the WRP, we took an iterative approach. This study was based on a literature review, observed practices, interviews with stakeholders dealing with circularity, and exemplifying case studies. First, we conducted desk research, including a literature review on the circular economy – focusing on business, policy, and innovation – and a policy analysis, with the geopolitical scope of the European Union and the Netherlands in particular.

We participated in a total of 21 meetings over the course of 15 months between July 2018 and September 2019 with circular hubs within the Netherlands to observe individual businesses and business-policy interactions and dialogues. Our empirical work following led us to observe potentially counter-transformative innovations operating under the label of circularity.

As we began to notice a pattern of transformations of wastes becoming used as resources, we conceptualized the paradox. For another related paper by the same authors (Greer et al., 2020), we conducted semi-structured in-person interviews (11) with members from a corporation, the Dutch government, and entrepreneurs working on circularity – from which we had also started to formulate the framework of this paradox. We reviewed these interviews to extract examples for the current paper.

After the theoretical prototyping for the WRP framework, we validated the conceptual innovation through another round of desk research and additional dialogues and investigation. This included a document analysis, involving grey literature and policy documents like project reports, governmental reports, and a third-party material exchange platform. We conducted two workshops to validate the concept, discussing and reflecting upon the WRP with experts (in waste and resource management, circular economy) (7), businesspeople (4), and representatives of national ministries (3). The WRP was additionally reflected in expert meetings with cross-societal stakeholders, such as CE experts, advisors, and researchers as well as in the context of a Food-Energy-Water nexus expert meeting with 37 researchers, practitioners, and policymakers, which took place in The Hague, Netherlands in October 2019.

After this further exploration, we conceptualized the four dimensions in which the WRP plays out: realizing the material, energy, economic, and social implications brought about by their respective dilemmas. The analysis of these dilemmas was informed by the three pillars of sustainability – environmental, economic, and social – to each of which a circular alternative should substantially contribute. For the purposes of this analysis, we also considered the "material" and "energy" aspects that make up the environmental pillar as separate entities, to be able to illustrate the tradeoffs and dilemmas encountered even within the same pillar, across these category lines. We then used the conceptual framing to look at specific cases in existing literature and empirical cases in an exploratory way to illustrate the different WRP dilemmas and implications empirically. Lastly, we analyzed the geopolitical, legal, and governance entanglements involved in, affecting, and affected by the WRP.

4. WRP: System dynamics and societal implications

4.1. Key dimensions of the WRP to a CE

Transforming a waste into a resource has potential to contribute to the advancement of the circular economy, as is generally intended. However, the problem lies when decision-makers, policy makers, investors, entrepreneurs, or consumers assume that the latter positive contribution is automatically true – when a material traditionally going to waste instead becomes an input to another product or process, thereby closing a loop. As desirable as that may appear, it must first be carefully considered how the transition of a waste to resource – i.e. WRP – affects CE in the long term and at what level of impact. It is crucial understand the major impact the WRP can have on society, businesses, and the transition to a circular economy. In order to validate our conceptual claims about the WRP and to further understand the inherent dilemmas and implications, we identified salient empirical illustrations, which we describe in the following section.

We highlight the dilemmas of the WRP along the three pillars of sustainability: environmental, economic, and social. Further, we have divided the environmental pillar's dilemmas and implications into "material" and "energy," because they are both very important – but also distinct – aspects of the WRP. We use these as our four guiding analytical dimensions, as shown in Fig. 2:

The perspective of the WRP helps to better differentiate the dilemmas and implications of the chosen examples.

4.2. Practical dilemmas of WRP dynamics

The WRP in practice leads to a variety of challenges for businesses. In this section, we discuss business models that create a new demand for an existing or temporary waste in a variety of sectors, and we examine the dilemmas they pose. Table 1 provides an overview of our selected illustrations.

The context surrounding WRP cases and their corresponding dilemmas in Table 1 is expounded upon in the following text.

4.2.1. Material dilemmas

A first case we identified was "*QMilk*," a German-based company designing textile products from the otherwise wasted milk in 2011 during a year of unintended national dairy overproduction. This surplus would have been thrown out (in principle) and have gone to waste – until the *QMilk* founder realized the casein (a protein present in milk) made a suitable structure to weave a silky fabric and launched her company based on this new product (Di Ciancia, 2017). Though this innovation seems to fill the criteria of a circular business model at first, it is important to examine more closely its implications for CE and dairy farms over the course of multiple years. Closing a loop, in this case (as well as others beyond), would actually incentivize overproduction – the opposite direction of CE.

"Too Good to Go" is an example of a Danish entrepreneur's approach to saving food waste. The concept behind the business is to procure remaining food from supermarkets, cafes, and restaurants at the end of the day, to collect and resell to consumers at a lower price than the original seller (Too Good to Go, 2020). This is an example of cascading (Campbell-Johnston et al., 2020), which – as a general concept – contributes to a circular economy. However, this too hardly incentivizes businesses to make the most accurate possible estimations of daily food sales. Knowing that they could still make profit on surplus food ordered, the financial disincentive of waste management costs for disposing of excess inventory is thereby removed. Cascading can slow loops, but a more efficient scenario would be to have avoided unnecessary food production in the first place.

Fig. 2. Guiding analytical dimensions of the WRP, as related to the transition to a CE.

4.2.2. Energy dilemmas

We also explored cases in which the attempt to lessen material waste results in increased energy use. This led us to the example of "*Precious Plastic,*" a platform for plastics recycling and 3D printing. Like many other similar companies, they convert the waste into plastic pellets, which are then used as filaments for 3D printers – causing a new demand for higher energy consumption. Furthermore, plastic is very difficult to recycle properly (Balogun and Oladapo, 2016), because of the complexity and variety of plastics recycling – each type requiring a unique sorting bin, heating temperature, and recycling process. Most consumers do not know how, do not have the time, or do not care to sort each unique type of plastic as needed; this results in a very low-value medley of recycled plastics, unsuitable for most potential applications.

Another such example was uncovered in an earlier work of these authors (Greer et al., 2020): a study addressing the drivers and barriers in the progression towards a transition to a circular economy. One of the top wastes of the multi-national catering company called "*Sodexo*" was orange peels, for which their innovation team found a circular solution. They paired up with "Spaak," a company that uses supercritical CO_2 gasification to extract limonene, 10-fold citrus oil and pectin from orange peels, paying Sodexo for their "waste" and effectively turning it into a resource – a manifestation of the WRP. The oranges for catering services are transported to Sodexo by truck. Because their peels are legally considered a waste, EU sanitation and health regulation laws mandate that they cannot be transported in the same vessel as foodstuff, i.e. this truck must drive away empty. Then, *another empty truck* must drive to Sodexo to pick up and transport the peels to the next site. This saves material from going to waste, but this discrepancy in consideration as a waste (law) vs. resource (companies) requires twice the amount of fuel and energy to make use of the good.

4.2.3. Economic dilemma

Further, we observed business models that have a waste stream as a critical input and build their business case based on the free access to this waste. "*GroenCollect*" is a small social foundation, with branches in several major cities in the Netherlands, that collects food residues from households and businesses at a discounted price (compared to what traditional waste management companies charge). For example, companies and citizens can place the old, no longer edible bread in the "bread bins," which is collected and repurposed as fuel to create biogas. Other materials are preserved in their highest-value state, such as old coffee grounds which can be used to grow oyster mushrooms (GroenCollect, 2020). The business model of GroenCollect could be put in jeopardy if the stale bread they collect as the backbone of their business suddenly becomes a priced commodity. In the context of a waste potentially being utilized in such a magnitude that a demand for it is created and a price is therefore assigned to it, waste-producing companies could actually profit their waste production, while SMEs and alternative startups with small profit margins (before the price assignment to the waste) could be put out of business when their input costs rise (too high), based on this new increase of cost to

Table 1
Dilemmas of the WRP explored in practice.

Dimension of CE	Example	Sector	Dilemmas in practice, as related to WRP
Material	QMilk	Fashion/Agriculture	Closing a material loop, which incentivizes overproduction
	Too Good to Go	Food	Cascading and value retention, which removes the financial disincentive of overordering (and thereby, overproduction of the goods ordered)
Energy	Precious Plastic	Plastics	Reducing plastic waste, which requires a new high energy demand to be processed
	Sodexo	Food/Chemical Industries	Reducing food waste, which requires extra transport and fuel (in the EU legal context)
Economic	GroenCollect	Food/Energy	Creating new use for an old waste, which may result in a potential commodification of waste and a new market barrier for circular SMEs
Social	Agbogbloshie	Electronics	Secondary material recovery, at a cost to human health

access waste. The same logic could be applied to and put in danger other innovative SMEs supporting the CE; a new barrier to the market would be created as a result of such waste commodification.

4.2.4. Social dilemma

Within the electronics industry, we identified a particular social dilemma directly tied to the WRP. When there is a discrepancy between the countries disposing of electronics and the countries in which they are disposed of the perception of value of a material output, it can lead to exposure to toxicity from manually dismantling waste electrical and electronic equipment (WEEE) at informal recycling plants (i.e. E-waste dumps), like in the case of "*Agbogbloshie*" recycling centers in Accra, Ghana. Agbogbloshie has achieved notoriety as one of the most polluted slums in the world by hosting the arguably largest informal electronic waste dump in the world. In this area of Ghana, the urban poor of Accra have been spending years recovering parts and metals extracted from electronics scrapped by Europe and USA (Grant and Oteng-Ababio, 2012). Just like at Agbogbloshie, other areas of Ghana, Kenya, Nigeria, and Liberia have been importing used EEE from the EU, where informal recyclers engage in work such as openly incinerating cables and plastic parts to liberate copper and other metals (Nordbrand, 2009; Secretariat of the Basel Convention, 2011). Although urban mining may reduce the extraction of virgin rare earth and critical metals, toxic residues from manually breaking down WEEE are left behind. These residues include localized concentrations of toxic waste, damaged ecosystems, and harm done to the bodies of the workers who perform much of the processing and sorting (Sullivan, 2014), highlighting the social injustices of current practices surrounding this example of the WRP.

4.3. Implications of the WRP dynamics and dilemmas for CE

4.3.1. Material implications

During the initial year of operation, "*QMilk*" indeed offered a viable, sustainable way to close a loop. However, this new business model was built entirely dependent upon heavy milk production; thus, for every year after the original outlier that sparked the business idea, it might have the reverse intended effect: having turned a waste into a commodified resource. Setting aside all of the negative effects associated with dairy farming – an industry whose sustained existence itself already creates substantial environmental threats (Mu et al., 2017; Gerber et al., 2013; Place and Mitloehner, 2010) – the overproduction (a practice to be avoided in general across all industries) became rewarded. Instead of disincentivizing overproduction through waste processing fees or other regulatory measures, the reverse occurred – a steady, constant demand for unnecessary waste. This indicates that the "circular" model could likely create a rebound effect: causing more material (in this case, milk) to be wasted in the long-term, overcompensating for the marginal efficiency gains on which the business was based.

In the case of "*Too Good to Go*," we identified the risk of removing the financial disincentive of food overproduction. If restaurant managers, for example, calculate that they will be paid for all the food they produce per day, this is hardly an incentive for accurate estimation of *per diem* food sales. If the overproduction of food was sure to be a net loss at the end of the day because of its associated production and disposal costs, there is a much greater chance that the procurement quantities will be more accurate estimations. With the integration of Too Good to Go into their supply chain, daily overproduction of food becomes a financial non-issue. Understanding the WRP encourages us to think critically, also particularly about the number of meals Too Good to Go advertises on their website that have been "saved." The advertised numerical value accounts for how many meals were bought and resold. However, this does not equate to saving wasted food, if that food might not have been produced in the first place (without the presence of a reseller).

4.3.2. Energy implications

Within the circular economy, the focus is by and large on material – rather than energy – streams. This puts policy and businesses striving towards circularity at risk for burden shifting: wherein the overall environmental impact is not necessarily lessened by reducing waste production, but rather shifted to a different life cycle stage or type of waste (Algunaibet and Guillén-Gosálbez, 2019; Jackson and Brander, 2019). 3D printing is extremely energy intensive (Christensen et al., 2019), and life cycle analyses of plastics therefore indicate that incineration at their end of life can often be more environmentally efficient than recycling (Khoo, 2019; Pivnenko et al., 2015). Furthermore, plastics deposited in recycling bins are often destined for oversea plants for final reprocessing, requiring much transportation fuel and energy (Mohammed et al., 2018). This illustrates a trade-off emerging from the WRP: exchanging material consumption for energy consumption.

In particular industries, we found that the legal definition of waste or the cumbersomeness of another structural procedure impeded the ability and feasibility of using a waste as a resource. As an example, in the food industry: as soon as a food-related byproduct leaves the walls of the building in which it was created, it is legally labeled a waste in the Netherlands (Ministry of Agriculture, Nature, and Food Quality, 2018). This can cause issues of accessibility for those innovators wanted to explore a way to close that loop, or – in the case of *Sodexo* – could create logistical complications which result in an increase of energy demand and carbon emissions.

4.3.3. Economic implications

GroenCollect's business model is based on the ability to take food waste for free and creating a product from which they can make profit. However, if larger businesses creating waste start to realize that they are actually offering a resource (because it is the input to something profitable) – not a waste – they may start charging for the material. This manifestation of the WRP would thereby commodify the waste, which would constitute a threat to both CE in general and particularly to this example of one business model with a positive environmental impact. In this sense, the WRP could also create a new market barrier, especially for new startups and SMEs. The WRP's economic implications especially affect these startups and SMEs, whose business models have a small profit margin and are based on the free or paid collection of waste.

4.3.4. Social implications

The discrepancy between nations about what is a waste and what is a resource can result in major social implications for cases where the WRP occurs internationally. As an illustrative example, in most countries of the Global North, a broken electronic device (e.g. laptop, tablet, mobile phone) is considered a waste. This "waste" is then collected and dumped, most likely in a country of the Global South, where it is not perceived as a broken laptop, but as a field of valuable metals. Under the current crude recycling methods, insufficient precautionary measures and protocol (if any) are taken towards worker protection (Leung et al., 2008). The endangerment of informal workers at waste dumps like in Agbogbloshie by handling WEEE is a direct social implication emerging from the Waste-Resource Paradox spanning country borders and cultural norms, in that large communities of people are unwillingly and perhaps unknowingly negatively affected as a result of the systematic international burden-shifting manner in which electronic waste is converted back into a resource. Because volumes of e-waste and e-scrap are projected to increase (Minter, 2013), it is with urgency that the social implications of the WRP counterproductive to a just CE are carefully considered and fully understood.

5. Synthesis and reflections

In this paper, we bring attention to a phenomenon that we call the Waste-Resource Paradox (WRP). Despite its widespread occurrence, until now it has gone highly unnoticed and understudied – not yet fully conceptualized to date. Through our illustration and analysis of the WRP, we argue that awareness of this phenomenon is crucial during our societal endeavor to transition from a linear to a circular economy, to understand the potential long-term and systemic implications of turning a waste into a resource. Furthermore, we implore policymakers, investors, entrepreneurs, and other decisionmakers to consider the WRP in their decision-making processes and evaluations for a more comprehensive understanding of if we are indeed supporting innovation that advances us towards our stated goal of a circular economy – i.e. material extraction and consumption reduction, highest value preservation, and social justice. We illustrated its manifestation in the context of selected cases from a European perspective with a global system view, to catalyze discussion about the WRP's potential ramifications.

a Linear economy lock-in and rebound effect

As entrepreneurship around circularity becomes saturated, it is possible that these business models based on using waste will create a demand, such that current regime incumbents are not incentivized to reduce or minimize their waste production by waste management costs. There is a future scenario possible wherein the demand of specific wastes streams becomes so entrenched in our industries and society that we unintentionally and contradictorily create a linear economy lock-in through an attempt to transition to a CE through optimization of the current linear system – rather than accelerating the necessary radical innovation fitting a new economy regime (CE). While Zink and Geyer (2017) have identified generally that there is a cap on global material circulation resulting from limited primary resources as well as a threat of rebound effects, the WRP perspective provides an understanding of the fuller picture. A recent estimate by UNEP on global patterns of material use derived from an MFA database arrives at 70 Gt/year or 10 tons/capita/year (UNEP, 2016). Such a rate of extraction and consumption of limited resources can result in natural resource depletion, climate change, loss of biodiversity, and uneven economic development (Schandl et al., 2018). Despite improvements in efficiency through innovation, these may actually lead to increased demand and thereby increased production and consumption. When the WRP is identified as occurring, it may serve as a warning signal for approaching a potential rebound scenario. In this way, it allows space to take preventative measures to curb or stop this effect from occurring before it becomes embedded in society.

b Tradeoffs with energy use and treating the symptom

The cases illustrated in this paper highlight the necessity to be cautious when ignoring trade-offs at the waste – energy nexus. The reduction of material consumption still runs the risk of resulting in increases in energy consumption. We must consider the whole system and entire life cycle of a product to ensure that a seemingly circular innovation is not simply shifting the environmental burden from the end-of-life phase to the manufacturing phase. As with the case of plastics recycling, it can be argued that recycling is only a compensation measure that involves objective and substantial material and energy loss in its process (Amini et al., 2007) – when a much more impactful innovation would address the source of the problem (i.e. ubiquitous plastic manufacturing and consumption).

c New market barrier for SMEs

Another tradeoff to consider is the new market barrier for startups and SMEs that the likely commodification of waste over time brought about by the WRP would create. As a price is assigned to a material currently allocated as a waste, this may cause trouble in a business model with small profit margins. It means that larger companies in the regime will outlast and/or jeopardize smaller organizations attempting to break the market barrier: a natural exclusion mechanism that increases the stability of the existing regime.

d Human health risks

A circular economy is not actualized unless it is just. The treatment of WEEE illustrates how the WRP across country contexts can result in the institutionalization of human health risks and systematized regular exposure to high toxicity. If we are to urban mine for critical and rare earth metals as a way to reduce and slow virgin material extraction, we must create worker protection laws and safety regulations to ensure that this is executed in such a way that large populations are not put in harm's way to do so. Here, it becomes clear that the WRP is not bound to geographical or administrative boundaries. Instead, it may require a transnational view to capture the emerging implications and in order to account for negative (social) impacts.

e Law as impediment to circularity

In the transition zone between a linear and circular economy, it is possible that multiple actors or forces involved in practice have opposing labels simultaneously. The legal system and regulatory systems provide boundary conditions for different forms of the WRP to emerge, while may also offer the instruments or policy mixes (yet to be designed) in order to address some of the ramifications and unwanted implications of the WRP. In the aforementioned example of orange peels as the material in question, two companies succeeded in creating a use for unavoidable orange peels in a circular way together. Yet, despite both of the active parties in the material exchange recognizing it as a resource, hygiene laws dictated that it be named and treated as a waste. Because of this, twice as many trucks were needed to move the material. While considerations for hygiene are undeniably important, this is an example of regulations creating a need for more fuel and transportation energy. It illustrates the need for critical thinking on how to uphold quality and safety standards while improving environmental efficiency. Furthermore, it raises the discussion of if and in which form novel regulations and standards emerge during the transitionary period bridging us from the linear economy towards a circular economy.

5.1. Caveats and limitations

The select evidence presented is not intended to convey the message that transforming a waste into a resource is counterproductive to circular economy. In fact, some actors and select industries appear to have devised a system for effectively reducing, and sometimes even eliminating, a certain material waste flow in a manner consistent with the core logic of CE. The risk lies when companies, organizations, governments, or investors assume that using a waste as a resource by finding a way to close a loop, by default, contributes to a CE. What this paper aimed to expose is that business models considered to be at least partially circular in everyday practice (and often presented, supported, and even funded as such) potentially may be working against a more fundamental transition.

The examples in this paper are intended to be illustrative of an important occurrence that needs to be addressed. The paper is not intended to deprecate any of the organizations described. We use them as an explicative instrument to drive more analytical thinking about the multi-sector societal implications of the WRP. Based on these, we hope to inspire discussion and criticism on what can truly qualify as “circular” and what consequences may result if the long-term ramifications in each of these societal sectors are not considered from the WRP perspective.

Similarly, it is important to note that the WRP should neither be conceived as solely good nor bad, but it calls for awareness around risks and uncertainties for new business models and a risk assessment of potential implications system wide. It is crucial to deal with the Waste-Resource Paradox, and understand its potential impact on society, policy, and waste (i.e. resource) management – which we must thoroughly and critically examine before accepting, welcoming, and investing in a circular innovation.

5.2. Implications for further research

The WRP is an inter-disciplinary phenomenon that requires multi-disciplinary research to be further studied. In this section, we recommend topics and questions for future research to address, which can further extend the findings of this paper.

While we have presented illustrative examples of how the WRP manifests in different sectors and material contexts, it appears relevant to substantiate our arguments with rigorous quantitative assessments of the WRP dilemmas. These WRP dilemmas have major implications for environmental impact assessment tools and modelling. For example: one of the most established and well-developed tools is a Life Cycle Assessment (LCA), used to evaluate the environmental impacts of a product or a service throughout its life cycle (during raw material acquisition, production process, use, and disposal of the product) (Ness et al., 2007). An LCA, by nature, looks at one product or process, but circular economy must be studied through a system lens. This incongruence in scopes can bring about misleading results, for example when an LCA would indicate an improvement in environmental efficiency of a product, which may have a net negative impact when considering other stocks and flows within the entire system. The WRP brings to light some of the complications of “allocations” in LCA, i.e. the explicit labeling of an outflow to be a bi-product (an output of value) or a waste (unintended stream released into the system with no positive economic value or contribution to another product). It also illustrates the shortcomings and inconsistencies in “demarcations” between what is included in the product system and what is excluded. A consequential LCA (Rebitzer et al., 2004) may offer an incrementally more holistic evaluation: evaluating the impact of a new policy or implementation with a micro-economic approach in background combined with an LCA approach in foreground. However, this tool is much more time- and resource-intensive, while still not offering a fully comprehensive understanding.

In our early stages of this research, we attempted an explicatory study analyzing historical price assignment to secondary materials over time and contextual variables, events, and influencing factors surrounding the monetary switch from waste to resource. However, after a thorough search, no such records or databases on which we could base this analysis could be found to exist. We recommend that future research applies *post hoc* analyses of historical cases of the WRP, which could offer predictive insight and/or warning signals of a WRP manifestation likely to occur. Building on our research in this way could also offer deeper insight into group and individual decision making to understand: how was a price assigned to or negotiated for a formerly non-commodified waste? Furthermore, there are no existing decision-support tools for actors in practice to help navigate the dilemmas highlighted by the WRP. For those striving to support circular innovation in an intelligent and meaningful way, modelling such systemic perspectives will be too complex; there appears to be a need in policy and practice for simplified “maps” (i.e. heuristic decision schemes) that provide orientation.

5.3. Recommendations for policymakers, investors, and entrepreneurs

By exposing the WRP, we hope to shed light on how to align short-term solutions with long-term visions. In some cases, it may actually be desirable that some “circular” innovations fail, considering if they will continue supporting the circular economy in the long run – or if they rather might have the reverse effect. This calls for policy and governance that helps navigating the WRP appropriately with the most sustainable outcomes possible, i.e. stronger legal and financial incentives for innovations acknowledging potential rebound effects and WRP dynamics.

5.3.1. Contract considerations

One potential solution for policymakers and investors to help lessen the problematic aspects of supporting circular innovation, elucidated by the WRP, is shorter contract or funding durations. For example, *QMilk* made good use of waste for the initial year of its solution for the dairy industry. However, funding and support should be limited to the time it takes to "right the wrong." Funders, policymakers, and other decisionmakers involved in such a contract should assess and re-evaluate it regularly, ensuring not to create a demand for continued, intentional overproduction.

The need for shorter contract durations can also be observed empirically in a case of municipal waste management. Within the Netherlands, many municipalities entered into long-term contracts with waste incinerators and waste separation companies that keep them locked in to the existing waste-based system (van Raak et al., 2014). Despite innovations for efficiency improvements made in waste sorting, reuse, and municipal recycling, cities remain locked in to producing a minimum amount of waste on a municipal level for decades – otherwise met with a fine (NOS News, 2014). Learning curves and more radical innovations are systematically ignored; shorter or more flexible contracts would allow for *adaptability*.

This assertion was supported in practice by an example from the Dutch Ministry of Infrastructure and Water Management. In an effort towards circularity in the furniture sector, contracts were reformulated to teach the skill of *repairing* existing furniture instead of *building* new furniture. This helped mitigate the "winners and losers" in transitioning to a CE discussion; thousands of builder jobs were not lost – only adapted. Furthermore, contracts were made for five-year periods so that, in the context of evolving innovations, a mutually beneficial and progressive contract for the Dutch Ministry and CE could be regularly updated and re-negotiated (Greer et al., 2020) to allow space for novel efficiency improvements.

5.3.2. Reflexive governance

The discussion of the preceding section calls for the implementation and practice of reflexive governance: a type of collective approach to cope with societal challenges – which must be predicated on a diagnosis of ongoing patterns and their constraints, how to act in their context, and considering how to improve them (Voβ, Bauknecht and Kemp, 2006). It refers to shaping societal development in the light of the reflexivity of steering strategies - the phenomenon that thinking and acting with respect to an object of steering also affects the subject and its ability to steer (Voβ and Kemp, 2015). The Waste-Resource Paradox demonstrates that governments, policy makers, and business managers (among others) should not blindly support innovation that appears to close a loop; these decision makers should regularly reflect on the short-term efficiency gains aligning with the long-term vision of circularity.

Along the same vein, funding support should be proportional to the long-term contribution to a circular economy. This can imply tiered funding or selected funding, in terms of the duration and/or amount of funding allocated – as directly related to their long-term impact. Evaluating policy, innovations, and investment opportunities through the WRP lens can expose and refocus companies relying on waste that ideally should not exist in the first place. Some may contribute now as a short-term fix, but we should aim to phase (the need for) them out as quickly as possible. Therefore, funding, policy, and other support should differ per innovation – continuing only so long as it aligns with a long-term circular strategy.

5.3.3. Lessons for entrepreneurs

The implications for CE of the WRP discussed in this paper indicate that we must not only consider single flows or single countries when attempting to accelerate the transition to a circular economy; rather, we must be cognizant of the interdependencies and indirect effects of innovations in such a globalized context. This resonates with a principal element of transition theory: such an examination makes clear the prerequisite and importance of systems thinking to address societal challenges. Similar to our recommendations to policymakers and investors, we strongly urge emerging circular entrepreneurs to evaluate the consequences of their innovation across time and space with the WRP in mind. We encourage new (and current) business owners and innovators to orient their creative development towards *process innovation* over repurposing waste (Henry et al., 2020). We implore them to be strategic, explorative, and self-reflective about their values and the long-term impact of their business in different lifespan and growth scale scenarios, and furthermore, to consider externalized (material, energy, economic, and social) costs and repercussions.

6. Conclusions

The WRP describes the phenomenon that a certain material at any time could be considered a waste or a resource: depending on the perspective of the handlers, the practicality of its use at the end of life, the cultural and geographical context surrounding it, and the legal backdrop on which is it evaluated. It is further paradoxical because the innovations related to the WRP are generally designed to close loops, reduce waste, and advance the transition to a circular economy. However, they may result in being counter-productive to CE by catalyzing a rebound effect of material use, creating a tradeoff with energy demand, bankrupting circular startups and SMEs, and posing a risk to human health. Unpacking the dynamics, dilemmas, and implications of the WRP creates awareness about risks and tradeoffs of building novel business models upon waste as a commodity and the implications this has in the transformation to a circular economy. Furthermore, it allows policymakers, investors, and business owners to think through the long-term implications of innovations with circular intents, and what these could mean for the progression towards a sustainable, just circular economy. It offers a widened decision-making capacity in their role during the transition zone on the path from a linear towards a circular economy.

CRediT authorship contribution statement

Rachel Greer: Conceptualization, Methodology, Validation, Formal analysis, Investigation, Data curation, Writing – original draft, Writing – review & editing, Visualization, Project administration. **Timo von Wirth:** Methodology, Validation, Project administration, Funding acquisition, Supervision, Writing – review & editing. **Derk Loorbach:** Methodology, Validation, Supervision, Writing – review & editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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