Journal of Cleaner Production 235 (2019) 1232–1239

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

City level circular transitions: Barriers and limits in Amsterdam, Utrecht and The Hague

Kieran Campbell-Johnston [a, *], Joey ten Cate [b], Maja Elfering-Petrovic [c], Joyeeta Gupta [d]

[a] Governance Group, Copernicus Institute of Sustainable Development, Utrecht University, the Netherlands
[b] The Hague, The Netherlands
[c] Kudelstaart, The Netherlands
[d] University of Amsterdam, the Netherlands

A R T I C L E I N F O

Article history:
Received 14 February 2019
Received in revised form
14 May 2019
Accepted 10 June 2019
Available online 12 June 2019

Handling editor: Cecilia Maria Villas Bôas de Almeida

Keywords:
Circular economy
Sustainable cities
Transitions
Circular cities

A B S T R A C T

Policymakers are embracing the circular economy (CE) as a means of harmonizing environmental and economic interactions, including at the urban level. Whilst numerous studies cover CE practices, few papers cover how it is being implemented and how cities (hotspots of material consumption, waste generation and disconnected pollution) are transitioning from linear-like processing of materials to a cyclical form. This paper addresses (a) how is the CE being applied and driven at the city level, and (b) what are the emerging transitional barriers and limits of such strategies? It compares the case studies of Amsterdam, Utrecht and The Hague, especially as the Netherlands is considered a CE frontrunner. Utilising document analysis of key national and city level strategies and 67 interviews, we show that the key municipal instruments include public procurement, zoning laws, capacity building and knowledge exchange and these can mostly be applied to municipal purchases and the construction sector. Practitioners perceived the initial barriers as knowledge of suitable technologies and deployment opportunities, the low quality of waste streams in comparison to the low costs of high-quality virgin inputs, the difficulty in addressing these issues at the urban scale, and the linear mindset of relevant actors. We argue that core limitations for these strategies and city level circular transitions include the instrumental scope and capacity to influence value chains and businesses, in addition to an overt focus on end-of-pipe actions as opposed to reducing and reusing resources. This research suggests that multi-level policy integration is needed to alter value chains to enable a greater reduction in material inputs and changes in actor behaviour.

1. Introduction

The exploitation of finite raw materials in an expanding global economy occurs within an evolving linear economic system since the Industrial Revolution. Using a 'take-make-consume-waste' approach, the environment is damaged from the extraction point to waste discharge beyond, in some cases, the regenerative capacity of natural ecosystems (Milios, 2018; Rockström et al., 2009; Urbinati et al., 2017).

Urban spaces, covering 7% of land area, are hotspots of consumption and waste, responsible for 75% of annual resource use, 75% of carbon emissions, 80% of energy consumption, and 70% of global waste generation (UN DESA, 2014; UNEP, 2013). A higher income per capita correlates to increased material consumption and waste generation; with the average European Union (EU) citizen producing 487 kg of Municipal Solid Waste in 2017 (Eurostat, 2018; Wiedmann et al., 2015). This will grow with rising urbanization in the Global South (Franco, 2017; Ma et al., 2016).

In response, governments and other actors are promoting the circular economy (CE) as a potential sustainable solution (Ghisellini et al., 2016; Kirchherr et al., 2017) ranging from top-down approaches in China (Elia et al., 2017; Lieder and Rashid, 2016) to multi-stakeholder engagement in the EU (Gregson et al., 2015; Van Leeuwen et al., 2018).

While CE publications are increasing, implementation challenges have scarcely been studied (Franco, 2017; Ghisellini et al., 2016; Lieder and Rashid, 2016) or critically interrogated (Gregson

* Corresponding author.Governance Group, Copernicus Institute of Sustainable Development, Utrecht University, Heidelberglaan 2, 3584, CS Utrecht, the Netherlands.
E-mail address: k.a.campbell-johnston@uu.nl (K. Campbell-Johnston).

https://doi.org/10.1016/j.jclepro.2019.06.106
0959-6526/

et al., 2015) especially at city level (Ghisellini et al., 2016; Wang et al., 2017). While Petit-Boix and Leipold (2018) quantified the impacts of circular urban strategies, and Prendeville and colleagues (2018, p. 174) mapped six "circular cities" in the Netherlands, Spain and the UK; Kirchherr and colleagues (2018, p.265) assessed transitional barriers to circularity at the EU level focusing on cultural barriers and calling for more critical analysis of CE barriers. Hence, this paper asks (a) how is the circular economy being applied and driven at the city level, and (b) what are the emerging transitional barriers and limits of such strategies?

This study undertakes a comparative assessment of Amsterdam, Utrecht and The Hague, three of the four major cities with a CE strategy within the Netherlands, a frontrunner in Europe (van Buren et al., 2016), which aims to be fully circular by 2050 (Ministry of Infrastructure and Environment (MIE) and Ministry of Economic Affairs (MEA), 2016). These case studies illustrate insights emerging from a literature review of 'circular economy, 'sustainable cities' and 'transition theory' synthesized in section 2. These cities have service orientated economies, with some industry in the periphery, but with differing population size. Per capita waste generation of Dutch cities is above the EU average (Eurostat, 2018). This Eurocentric focus is justified as Europe has a very high material footprint (Tisserant et al., 2017). Moreover, the lack of in-depth analysis of practical applications, namely city-level CE transitions, validates such an exploratory approach; in particular by focusing on the experiences of CE frontrunners, which could produce important lessons for other cities. We used primary (67 detailed semi-structured interviews in Amsterdam (25), The Hague (18) and Utrecht (24) in 2018) and secondary data (from relevant city and central government policy documents used to promote the CE). This data was contextualised to construct the history, focus and trajectory of CE in each city within the national approach, going beyond mapping approaches (see Prendeville et al., 2018) to consider the transitional process, instructional drivers and experienced barriers.

This paper reviews the literature on CE, urban sustainability and transitions (see 2), the policy context of the case studies (see 3), and presents the case study barriers (see 4) before drawing conclusions (see 5).

2. Literature review

2.1. CE origins and principles

Authors define CE differently (Kirchherr et al., 2017), citing the limits of planetary resources in "Spaceship Earth" (Boulding, 1966), the need for closed looped cycles (Pearce and Turner, 1990) and general systems theory (Bertalanffy, 1968). Initially (1970–1990) CE-related practices focused on process outputs through waste management and treatment policies (i.e. cradle-to-grave policies). Between 1990 and 2010 an emerging holistic focus promoted eco-efficiency, within industrial ecology systems that resembled natural ecosystems (Ghisellini et al., 2016) and a shift to cradle-to-cradle (early CE discussions) policies, i.e. reusing materials instead of generating waste (cradle-to-grave). Although early papers covered the material cycles (Vellinga et al., (eds.), 1998), it is only since 2010, that the third framing of CE emerged looking at resource prolongment and preservation, lifecycle thinking and closing material and energy loops (Blomsma and Brennan, 2017; Reike et al., 2018) and became more influential. CE seeks a paradigm shift from linear to circular practices which reduces the demand for virgin materials (currently 90 B tonnes annually) in production/consumption cycles (Genovese et al., 2017; Lieder and Rashid, 2016), to decouple economic activity from environmental pressures (Cullen, 2017; Elia et al., 2017) and promotes a restorative and regenerative economy by intention and design (Ellen MacArthur Foundation, 2013).

A CE uses the R-principles (Ghisellini et al., 2016; Reike et al., 2018), ranging from a 3R (Reduce-Reuse-Recycle) in China through 5Rs (Reduce-Reuse-Remanufacture-Recycle-Recover) to 10Rs (Kirchherr et al., 2017). In a heuristic and sequential manner Reduce refers to reducing materials used in production; Reuse requires additional product use without or marginal adaptation; Remanufacture brings an item back into functional use; Recycling involves using material components in different applications; and Recover captures energy embodied in material/waste through incineration/methane extraction (Ghisellini et al., 2016; Reike et al., 2018).

2.2. Sustainable cities/urban sustainability

Urban activities have impacts far beyond their borders often calculated through their ecological footprint (i.e. the natural capital needed for human activities) (Rees, 1992). City authorities have tried to reduce this footprint through eco-towns/cities which redesign urban landscapes and industry around eco-environmental and biomimicry concepts (Ghisellini et al., 2016; Roseland, 1997); smart cities which gather and optimise data for efficient resource use (Prendeville et al., 2018); and high density compact cities which use space and transport optimally (Dajani, 1974; Jabareen, 2006); in addition to 'sustainable' waste management.

A 'circular city', the newest iteration of urban sustainability initiatives, increases the 'added value' of urban metabolism (Cobo et al., 2018; Kalmykova and Rosado, 2015; Kennedy et al., 2011; Ribić et al., 2017) by building on industrial ecology (Milios, 2018) and integrating and redesigning infrastructure, logistical services, industries, and the socio-cultural system at multiple levels of governance (Milios, 2018; Mirata and Emtairah, 2005; Ness, 2008; Zhijun and Nailing, 2007), including more recently on social consumption (Petit-Boix and Leipold, 2018). European cities show that CE requires partnership with multiple stakeholders (Prendeville et al., 2018).

2.3. Transitional barriers to, and limits of circularity

Transition theory assesses how systemic changes occur across scales, sites and temporal manifestation within economies, institutions, technologies, cultures and beliefs (Geels, 2011; Rotmans et al., 2001; Seeliger and Turok, 2013). It includes a (1) *pre-development phase* (the status-quo); (2) the *take-off phase,* where change is initiated; (3) the *breakthrough or acceleration phase*, where systematic change manifests; and (4) the *stabilization phase,* where a new status quo is achieved (Rotmans et al., 2001). It can be driven by regulatory measures and normative expectations, infrastructure development, knowledge sharing, suasive measures and financial support (de Haan and Rotmans, 2011; de Jesus and Mendonça, 2018, p.77; Frantzeskaki and de Haan, 2009).

While transitions can be spontaneous or planned, understanding how they can be successfully managed is policy-relevant. The complex non-linearity of transitions imply that while they cannot be controlled (Geels, 2011), their direction and trajectory can be influenced (Kemp and Loorbach, 2003), combining long-term thinking with short-term policies and linking multiple stakeholders and multi-level aspects (Rotmans et al., 2001), although this is challenging (Jordan and Lenschow, 2008). Initial actions should be flexible, experimental and guided by the precautionary principle to prevent undesirable lock-in and enable promising innovations (Rotmans et al., 2001). Governments facilitating transitions often include strategic activities in long-term visions; tactical activities linking strategies to visions; operational activities, linking everyday activities to visions; and reflexive activities including monitoring and assessment (Kemp and Loorbach, 2003).

A CE transition requires a shift to systems thinking (Urbinati et al., 2017). Barriers to transition (de Jesus and Mendonça, 2018, p. 78; Kirchherr et al., 2018) are *hard* – technological (e.g. the difficulty of circular design, upcycling and high-quality remanufactured products) and market/financial (e.g. low virgin material prices and high upfront investment costs make 'circular' products more expensive), and *soft* – institutional/regulatory (e.g. rigid rules and political disagreement) and cultural (e.g. consumer habits, short-term profit orientated businesses cultures and the niche nature of CE). Generally, technological barriers are less problematic than the other barriers (Kirchherr et al., 2018), making 'soft' barriers 'hard' ones and often leading to a nearly exclusive focus on recycling.

However, the high expectations from CE may have blinded policymakers to its limited socio-environmental benefits (Korhonen et al., 2018a,b; Milios, 2018) as infinite recyclability and material circularity is not possible (thermodynamic laws), since materials lose their inherent properties over time; cycling secondary material stocks may not reduce extractive activities because of stock accumulation and growing demand (Fellner et al., 2017; Park and Chertow, 2014) including from the rebound effect (Zink and Geyer, 2017); the higher energy needed for reusing wastes offsets expected benefits (Gregson et al., 2015); and CE discussions have ignored the role of administrative boundaries (Korhonen et al., 2018a,b).

3. Case study context and description

3.1. The circular economy in the Netherlands

The Netherlands has stimulated CE-related policies since the 1980s through increasing recycling and reducing landfilling of unsorted (household) waste. These included a landfilling tax, landfilling ban and an incineration tax (Dijkgraaf and Gradus, 2017); resulting in municipal solid waste recycling rates above the European average (Eurostat, 2018).

Explicit CE discussions began in 2012, which coalesced around a formal programme in 2016 (MIE and MEA, 2016). This programme was presented to the Government in January 2017, with policy suggestions following in April 2017 and five transition agendas outlined in 2018 (MIE and MEA, 2016; Rijkswaterstaat, 2018).

The 2016 CE strategy aims to make the Netherlands 'fully circular' by 2050, with an interim target of a 50% material reduction of primary raw materials (minerals, fossil and metals) by 2030 (MIE and MEA, 2016). Voluntary agreements, or covenants with businesses, known as the 'green deal', are expected to stimulate CE activities and reach the aforementioned target; voluntary agreements between industry and governments are widely used and accepted in Dutch environmental policy (c.f. Rouw and Worrell, 2011). Cities and provinces are identified as the vehicles for implementing CE. The 2016 strategy sets out a circular vision, the material streams prioritised, and the proposed interventions and instruments. These can be summarised as:

a) **Circular vision**: CE is promoted to ensure long-term resource security through efficient and better-quality raw material use, replacing fossil-fuel based materials with 'sustainably' produced ones, and developing efficient new production methods that prioritise the use of renewable/sustainable resources. Interventions are to be pursued at multiple scales, including initiation by 'pioneering cities'.
b) **Material focus and descriptive targets**: include *biomass and food* which must be reused in some capacity; *plastics* must increase recycling and introduce bio-based plastics; the *manufacturing industry* must be made aware of future supply risks; the *construction sector* should optimise material throughput and reduce carbon emissions; and *consumer goods* should promote good consumer habits including sharing and repairing activities.
c) **Interventions and instruments**: include regulation, market initiatives and knowledge sharing measures to move economic and social activities towards a more circular and sustainable form. Regulatory changes should allow higher levels of waste utilization by changing the definition of waste. Market interventions include increased taxation of landfilling and incineration and financing circular projects, whilst knowledge development includes learning programmes and knowledge exchanges.

3.2. Case study 1: Amsterdam

Discussions on CE began in Amsterdam in 2013. The concept was adopted in the Amsterdam municipality's sustainability agenda in 2015, and an action agenda was initiated in 2016, which aimed to make the city a frontrunner in circularity. This agenda sought collaboration between multiple actors (local businesses, companies and citizens), whilst prioritising two material streams: organics and construction. The key intentions for the organic stream included developing a biorefinery hub, cascading organic residues (i.e. biomass production) and extracting phosphate from waste residues. One definitive target was set: 65% organic separation by 2020 (Circle Economy et al., 2016). The intentions for the construction chain included smart design, dismantling and separation, reuse and recycling facilitated by developing a secondary market and material bank. Institutional instruments include market mechanisms (e.g. tax incentives for circular business practices); regulatory measures (e.g. zoning laws, demolition contracts and public procurement); infrastructure development for waste collection, storage and refinery hubs; capacity building amongst stakeholders (i.e. workshops); knowledge exchange and development through platforms for material and product exchange; and suasive measures, i.e. using the municipality as a platform to showcase and encourage circularity.

The two material chains prioritised within the city strategy represent the largest (volume wise) material streams for the municipality. This is clearly seen as the most effective area for designing interventions. CE actions are framed in conjunction with concerns over local employment, resource efficiency and climate change mitigation, with the proposed actions presented as tangible measures to shift from global to local material cycles. Critically, the agenda gives greater attention to lower options within the CE hierarchy, e.g. recycling, reflecting assertions that circularity (from a policy perspective) is overtly focused on end-of-life practices (Milios, 2018). The city's singular target further illustrates this perspective.

Fieldwork for this case study focused exclusively on the construction chain, talking with informants about the design (e.g. modular, material passports, design for disassembly), construction (e.g. recycling and (re)using local secondary materials) and demolition (e.g. urban mining, high-value demolition and waste separation). The implementation of CE actions reflects the desire to reduce material inputs and internalise and extract value from previously externalised high-volume streams. Whilst the actions are within the pre-defined regulatory framework of the municipalities own projects (i.e. zoning and tendering), yet whether private actors will willingly adopt them remains questionable. Despite consideration of the entire chains, questions remain on whether disconnected actors can effectively collaborate.

3.3. Case study 2: The Hague

The Hague signed the National Resource Agreement in January

2017, following the national government's ambitions. Immediate actions include participating in multiple green and city deals, researching current CE opportunities in order to increase environmental resilience, increase employment and decrease CO_2 emissions, whilst stimulating the economy. The Hague is working towards an integral action programme, including (1) public administrations and governmental agencies; (2) construction and real estate; (3) the trade and commerce sector; and (4) households, which is supported by constructed coalitions between the abovementioned actors. Through interacting with these sectors, the municipality is examining the requirements for a circular transition, what the jurisdictional, economic, technical, and social barriers are, and their role as an institution within this. However, during the field research period, no specific targets were set by city authorities.

Fieldwork focused on the role of public administrations and government agencies, examining how this sector could become circular. Respondents indicated that the municipality aims to incorporate CE principles in its future policies and procurements. However, no constructive targets and strategies have been officially set, leading to the conclusion that the city is in the predevelopment stage of the CE transition (Kemp and Loorbach, 2003; Rotmans et al., 2001). The municipality calls for eliminating waste through product reuse and material recycling and promoting the sharing/service economy and product service systems to realise alternative consumption patterns. However, whilst the municipality appears to have ambitions, it lacks the institutional willingness and capacity to lead the process; instead, relying on voluntary participation. Hence, it is questionable whether this voluntary, less regulatory approach is adequate for realising any ambitious CE goals.

3.4. Case study 3: Utrecht

In 2015, provincial stakeholders including the municipality of Utrecht expressed an intent to move towards CE (Cramer, 2015). An exploratory document, ‘Towards Utrecht Circular Region (2015)’, laid down the long-term shared vision, goals and strategy and short-term concrete goals; material flow assessment; multi-stakeholder participation and implementation strategy; and the creation of a knowledge database and network. Subsequent research highlighted the construction sector as a suitable place to initiate action (Bastein and Rietveld, 2016). From this, the municipality of Utrecht set three priorities that focused on circular procurement, waste collection and circular construction and demolition (Utrecht, 2017).

Key targets proposed included purchasing 10 percent of circular goods and services by 2020, a target exceeded by 3 percent in 2018 (i.e. 13%) (Utrecht, 2018, 2017). In addition, household waste separation targets were raised from 45 to 50 percent household separation in line with EU targets. Buildings using CE norms and demolition were recognised to have high potential as the city has development ambitions. This will be promoted through including circularity in policies for area development and construction projects, environmental impact tools and collaboration platforms (Utrecht, 2017); measures to realise these ambitions include circular pilot projects, voluntary agreements and tendering applications for developers. Fieldwork focused on the construction sector and circular procurement, which highlighted fragmented policies and an inconsistent understanding of CE between stakeholders. Moreover, the lack of financial support and transparency in regards to the role of the municipality in CE is perceived as preventing its further development.

3.5. Summary

These cases illustrate how CE is being implemented within these cities, including the differing priorities and focuses; Amsterdam and Utrecht have prioritised specific areas (e.g. construction) and set targets, whilst the Hague was still considering its approach. From this, CE at the city level can be understood as measures to internalise, narrow and close previously externalised material throughput to attain additional use and/or added value within the city parameters, whilst contributing to the city's sustainability objectives through utilising the R-principles. An underlying theme is the intention to localise previously dispersed material sources, indicating that there is an embedded feature to city level CE applications. These are driven through available instruments, predominantly procurement, tendering, and stakeholder collaboration (see Table 1).

The priorities of each city fit into the broad national aims, with Utrecht and Amsterdam focusing on national priority chains, e.g. construction. Interestingly, these municipalities focus predominantly on end-of-pipe measures or lower R-options, with no specific measures for reducing the overarching material use. CE necessitates redesigning material lifecycles to reduce the volume of materials used. However, waste is generated unintentionally and is (usually) not meant for use, whilst the extraction of virgin materials is done for a specific purpose (Park and Chertow, 2014). Therefore, augmenting secondary materials to reduce inputs is challenging. These case studies reflect the broader trend within EU CE practices of prioritising waste management and end-of-pipe valorisation (Milios, 2018). If the fundamental aim of CE is reducing material volumes to address resource insecurity and scarcity, then the lack of commitment to this shows the limited focus of these cities circular capacity.

4. Findings and discussion

These above results describe the context in each city (in relation to the national), which answers our first research question. This section presents the most recurring and prevalent themes that concern the barriers and limits of each city's circular transition. Themes are grouped around their respective category, i.e. the barriers and limits. The subsection on barriers follows the *soft* and *hard* categories of de Jesus and Mendonça (2018) and is completed with the additional category called system level challenges.

4.1. Hard barriers

4.1.1. Technological

The literature generally regards technical and technological issues as relatively minor challenges (Kirchherr et al., 2018), and indicates that integrating design in circular processes is key to realising a restorative system (Ellen MacArthur Foundation, 2013). However, practitioners argued that adopting circular design was difficult, particularly because the knowledge of suitable technologies and how to apply them is challenging especially with respect to integrating take-back systems and reverse logistics (cf. Ritzén and Sandström, 2017). Reusing different qualities and quantities of wastes implies collecting, separating and making them useable for new production processes. While policymakers see this as easy (“[with] technology we can do a lot”), businesses/practitioners are struggling to assess waste quality for reuse in technical processes. This is perhaps not surprising given that all three cities are in a preliminary stage of CE transition, but it indicates the potential fragmentation of expectations and experiences between groups.

The basis of the circular city revolves around deriving added value, utility and closing material cycles from the city's urban metabolism (Cobo et al., 2018; Kalmykova and Rosado, 2015; Kennedy et al., 2011). Whilst knowledge of each city's key waste/material streams was high, systematic knowledge of the quantities

Table 1
Implementation and barriers for the cities of Amsterdam, Utrecht and The Hague.

	City		
	Amsterdam	The Hauge	Utrecht
Sector(s) and targets	*Organics/biomass* Separation of organics for reuse – 65% by 2020. Bio-based refinery for energy generation, nutrient recovery, and cascading organic flows. *Construction* Smart design of buildings, dismantling and separation of materials for reuse, high-value reuse of materials and resource bank for future projects.	Public administrations and governmental agencies; construction and real estate; the trade and commerce sector; and households. Realise a CE by 2050	*Governmental agencies* 10% of procured good and services by 2020 (13% reached in 2018). *Construction and demolition sector* Promote circular design and demolition, high value reuse and establish a secondary materials market.
Instruments	Zoning laws, circular permits, taxations on grey waste, capacity building through knowledge hubs, public procurement, infrastructure renovation and suasive engagement/communication.	Industry collaboration, implementing circular principles into policies, circular procurements and permits, suasive engagement.	Building permits, voluntary agreements, facilitating community engagement, public procurement, promoting best practices and developing CE knowledge base.
Barriers (all cities) *Technological*	Adopting circular design and applying suitable technologies; knowledge of material quality and quantity.		
Market/Financial	Financing of CE businesses models (temporal considerations); up-scaling/mainstreaming pilot projects; and low cost of virgin materials relative to secondary ones (linear lock-in).		
Regulatory	Legal definition of waste restricts specific subsequent use; instrumental scope limits municipalities capacity to ensure compliance, global production and material flows go beyond scope of municipal instruments; multi-level policy integration on standards and material regulations. Consequently, municipalities cannot reach a higher level of circularity without multi-level policy integration.		
Cultural	Ingrained linear mindset and lack of value chain thinking/collaboration; hesitancy/unawareness of companies to integrate CE practices and business models; consumer behaviour towards secondary/circular products; knowledge of how to use residual material streams is unclear.		
System level challenges	City parameters restrict the planning and scope: this requires greater space for the coordination of reverse logistics.		

and quality of material streams remains elusive. As one municipal advisor for Amsterdam stated, “knowing exactly the quality of what you take out is the most challenging”. This was particularly acute within the construction and building sectors, which lacked comprehensive knowledge of availability of specific material stocks. Solutions such as material passports and urban mining have been proposed as viable options, through mapping and documenting the material properties and quantities (Koutamanis et al., 2018); however, this process is at a very preliminary stage. Amsterdam is the exception having conducted an urban mining scan; however, the knowledge generated remains untested and requires further dissemination to wider audiences. Therefore, the issue of material quality within the monitoring system remains fundamental for secondary materials because many are currently downcycled, i.e. used in ‘lower value’ applications (Blomsma and Brennan, 2017). This ‘knowledge gap’ prevents the effective deployment of the relevant technical solutions.

Technological issues emerged as a moderate concern, although this differed between cases. The issue of lock-ins in existing socio-technical systems, which are often challenging to overcome, should not be overlooked in the practical process of CE transitions (de Jesus and Mendonça, 2018). Further research is needed into the extent to which CE technical issues are fundamentally inhibiting its progression.

4.1.2. Market/financial

Broader market dynamics, norms and pressures represent the backdrop to finding an alternative economic paradigm. Informants, particularly in The Hague, discussed the challenge of making a viable CE business case. Financing CE business models, such as products-as-services and products via secondary material streams, is an established theme within the literature (Lüdeke-Freund et al., 2018; Ritzén and Sandström, 2017). Such features were particularly prevalent in Utrecht and Amsterdam as these cities are integrating CE practices in building tenders. Yet, encouraging building developers to integrate measures such as material passports and design for disassembly is challenging, because they don't necessarily receive the financial benefits and consequently have a lower incentive to do so. The conundrum of split incentives when thinking along material life cycles and allocating costs and benefits remains an on-going struggle in getting such CE activities started.

To promote CE within each city, pilot projects were showcased, indicating that CE practices are still a niche element within the broader sustainable development network (Kirchherr et al., 2018). The case studies illustrated a high degree of integration with broader sustainability objectives; for example, Amsterdam municipality uses CE to engage with individuals with difficulty accessing the labour market, i.e. the long-term unemployed. Yet, most stakeholders argue that mainstreaming the pilot projects is unlikely (they had “never seen it happen”). Stakeholder collaboration is viewed as essential in not only developing CE business models, but also upscaling them (Whalen et al., 2018). Value chain collaboration can ensure such practices are successful, yet the bounded spatial proximity of urban stakeholders presents a fundamental challenge to pursuing this.

A focus on a city's material flows enables the identification of areas to close material loops, specifically through using secondary materials. Respondents discussed the process of utilising such streams; instruments, such as procurement and tendering contracts by the municipality were seen as a way to stimulate this market. The current lack of such a market, although viewed as an issue, was a lower systematic challenge than the low cost of virgin materials and contamination within secondary streams (Baxter et al., 2017; Kirchherr et al., 2018). The issue of cost has been extensively studied, particularly in relation to bio-based products versus fossil-based ones in a CE (Budzianowski, 2017; Stiles et al., 2018; Venkata Mohan et al., 2016). Respondents from companies asserted that the higher costs and lower guarantees of secondary material streams prevented them from adjusting supply chains to use the city's material by-products; this indicates the broader economic and regulatory factors which cannot be explicitly tackled directly by city level policymakers. Moreover, stakeholders discussed the challenge of ensuring the quality and consistency of secondary materials supplies, with local material banks being highlighted as a potential solution. The state of affairs is currently concerned with subsequent uses of secondary materials; however, the recognition of thermodynamic and recycling limits was not as explicit, with policymakers primarily concerned with developing this new market. Thus, market forces and the value of secondary materials emerged as a consistent barrier that moves beyond the city boundaries.

4.1.2.1. *Soft barriers*

4.1.2.1.1. Institutional/regulatory. The literature argues that institutional/regulatory barriers critically hinder CE development (de Jesus and Mendonça, 2018; Kirchherr et al., 2018). However, our stakeholders found that there was flexibility in the policy framework encouraging CE activities. This may reflect the interview sample or the integration with the national policy framework.

Using residues and material by-products that are demarcated as ‘waste’ is already recognised at the European level (WFD, 2018/851). However, municipal officials consistently raised the concern over *how* a CE at the city level should be measured, including the suitable indicators and parameters for success. The question of measurement for a CE is rapidly evolving in the literature (Di Maio et al., 2017; Elia et al., 2017; Jacobi et al., 2018; Makarichi et al., 2018; Park and Chertow, 2014), yet, a consensus at the national level is lacking. Indeed, the approach of each case study city, also comparable to the EU level, is more concentrated on adapting and measuring through end-of-life activities (Gregson et al., 2015; Milios, 2018). This question of measuring CE is a new challenge for both academics and practitioners. Yet, if CE is to be established as a transformational idea, consistent measurement of place and product, which reflects its normative ideals, must be established in order to prevent incoherence and greenwashing.

The scope of instruments emerged as a factor limiting CE practices. Primary instruments, including tendering contracts and procurement, were generally applicable for municipal led projects, including new developments and maintenance. Beyond those directly involved, policymakers expressed reservations on the inability to compel greater compliance from companies, working, at present, only through suasive measures. Moreover, the broader context of global material and product flows, although concentrated in consumption in urban spaces, goes beyond these cities sphere of regulatory influence, fundamentally limiting their strategic ability to realise a higher degree of circularity and self-sufficiency without coherent multi-level policy integration.

In addition, the multi-level complexity of city level circular transitions are such that different policies at different levels can hinder transitions. Standards and material regulation are predominantly set at the national and regional level, which makes it more difficult for local policymakers to encourage recycling of these materials. Moreover, adjusting the legal framework, so that secondary materials are more attractive cannot be done by cities. Several municipal officials expressed frustration at the lack of new devolved instruments for CE measures given the cities focal status in the national transitional roadmap (MIE & MEA, 2016).

4.1.2.1.2. Cultural. Previous research asserted that cultural barriers were the most prevalent challenge between stakeholders (Kirchherr et al., 2018). CE is framed as requiring a ‘paradigm shift’ in systems thinking, involving multiple stakeholders (Urbinati et al., 2017). The embedded nature of the “linear mindset” within firms indicates the challenge in thinking and acting in a circular manner (Franco, 2017, p. 837). Specifically, this involves thinking about product and material value/use over a long(er) period of time (‘long termism vs. short termism’), which runs counter to many current practices. This interconnects with the above market, technological and regulatory barriers, where personal reservations underpinned each concern. For example, ‘short-termism’ can inhibit investment in circular businesses which operate on a longer timespan (e.g. product service systems). Whether CE evolves into the transformative solution it is presented as, therefore, depends on the extent to which the cultural lock-in is overcome.

In addition, respondents referenced the need for a fundamental ‘mind-shift’ in how consumers and companies viewed CE practices. For instance, one company which produced bricks made from industrial by-products asserted that most companies do not think about the utility of their wastes. These practices, commonly used in industrial symbiosis and eco-parks (see Jacobsen, 2006), remain outside the norm, with the above being the exception rather than the norm. CE research has illustrated how value can be created from material by-products, through cascading, open and closed material value chains (Ranta et al., 2018; Yang et al., 2018). Yet, non-CE oriented companies are hesitant to make the transition, either unaware of the potential of CE activities, or are afraid that it might reduce the quality of their products. Consumers are another group whose behaviour and preferences (‘mentality’) inhibits the acceleration of CE practices. All municipalities placed emphasis on changing consumer habits by encouraging the reuse and repair of items.

Moreover, ‘knowledge’ of *how* material streams could be best (re)used was a fundamental knowledge gap. Material reuse depends on whether residual streams can be fully incorporated back into the economic process. Yet, how/where to direct them and in which capacity/purpose was explicitly lacking within the current discourse. This reflects the ambiguity of the underlying aim of CE as articulated by different stakeholder groups. The literature on CE calls for the reduction of virgin inputs via closing and narrowing material and energy loops (Geissdoerfer et al., 2017). However, such strategic thinking and knowledge about how exactly to connect outputs to inputs is less explicit in the case studies, a potentially daunting barrier considering the Netherlands target of reducing primary material use by 50% by 2030.

4.1.2.2. City level system challenges. In contrast to previous CE research, the city level scope mandates a spatial focus in which to examine its activities. Stakeholders acknowledged the restrictions due to ‘space’ for storage and transportation. This interconnects with the challenges of logistics and planning for circular activities, which requires greater value chain collaboration (Gregson et al., 2015). However, such practices require alternative logistics and planning, which can prove complicated to integrate. The case of the Netherlands shows the importance of planning for a CE on multiple scales simultaneously in order to more successfully attempt closing material loops. Yet, this level of integration has not yet been fully developed. Whether it does, remains an on-going feature to examine.

5. Conclusion

This research examined the emerging barriers and limits of three Dutch cities transitioning to the CE. It concludes that key municipal drivers for CE include public procurement, zoning laws, voluntary agreements, capacity building, taxation of waste, and knowledge exchange. Such actions are attempting to internalise and close previously externalised material throughput to create added value based around the local economy; with the construction sector a common place for CE interventions.

This research further contributes to the evolving CE literature by in-depth description of the specific barriers and limits concerned with these applications arising at the city level. *Hard* barriers include (a) adopting circular designs and applying suitable technologies; (b) knowledge of material quality and quantity within the city; (c) financing CE business models; (d) upscaling pilot projects; (e) low costs of virgin materials. *Soft* barriers include (f) measuring CE; (g) multi-level regulatory complexities; (h) short-term business mentality (linear mindset); (i) knowledge of useful material applications; (j) and space and logistics. These barriers are interconnected and interdependent which hinders the transition to a CE. Higher costs and low guarantees of secondary materials prevent companies from adjusting supply chains to city by-products. The price disparity between 'virgin' and 'secondary' material streams, goes beyond the cities scope, necessitating action from a higher level. Therefore, the importance of multiple level policy-integration and coordination between scales and actors is necessary to address city level barriers.

Of these barriers, the cities are fundamentally limited by their instrumental capacity and CE-focus. Namely, the limited scope of the instruments to affect and compel stakeholders along the value chain means that these case studies are prioritising lower value CE options, e.g. recycling. There is little focus on higher value R-options, indicating the limited approach towards a holistic CE transition and capacity to do so at this scale. CE is commonly presented as a 'transformative' and paradigm altering new approach to sustainability, yet this element appears not to have been manifested, even in these frontrunning cases. Thus, greater attention to higher R-options is needed to address the issues CE aims to overcome.

This research has several limitations. Whilst this research used multiple interviews to present the transitional barriers, it did not establish the severity of barriers as experienced by stakeholders. A follow-up survey of the above preliminary results could be extended to a wider array of cities. Future research should conduct comparative research into the transitional pathways of non-European cities, to establish regional and geographical divergences. Moreover, subsequent research could give validation to the assertion that CE activities in the Netherlands are primarily end-of-pipe/lower R-options by mapping companies and practitioners.

Declaration of interest

None.

Acknowledgements

We would like to thank the interviewees and others who participated in this study including the reviewers of this paper. A special thank you to Tomás Ramos who reviewed an earlier version of this paper.

References

Bastein, T., Rietveld, E., 2016. Circulaire Potentie Voor Utrecht.
Baxter, W., Aurisicchio, M., Childs, P., 2017. Contaminated interaction: another barrier to circular material flows. J. Ind. Ecol. 21, 507–516. https://doi.org/10.1111/jiec.12612.
Bertalanffy, L. von, 1968. General System Theory. foundations, development, applications.
Blomsma, F., Brennan, G., 2017. The emergence of circular economy: a new framing around prolonging resource productivity. J. Ind. Ecol. 21, 603–614. https://doi.org/10.1111/jiec.12603.
Boulding, K., 1966. The Economics of the Coming Spaceship Earth (New York).
Budzianowski, W.M., 2017. High-value low-volume bioproducts coupled to bioenergies with potential to enhance business development of sustainable biorefineries. Renew. Sustain. Energy Rev. https://doi.org/10.1016/j.rser.2016.11.260.
Cobo, S., Dominguez-Ramos, A., Irabien, A., 2018. From linear to circular integrated waste management systems: a review of methodological approaches. Resour. Conserv. Recycl. 135, 279–295. https://doi.org/10.1016/j.resconrec.2017.08.003.
Cramer, J., 2015. In: Strategische Verkenning ' Op Weg Naar Cirkelregio Utrecht.
Cullen, J.M., 2017. Circular economy: theoretical benchmark or perpetual motion machine? J. Ind. Ecol. 21, 483–486. https://doi.org/10.1111/jiec.12599.
Dajani, J., 1974. Compact city: a plan for a livable urban environment by George B. Dantzig; Thomas L. Saaty. Oper. Res. 22, 446–448.
de Haan, J. (Hans), Rotmans, J., 2011. Patterns in transitions: understanding complex chains of change. Technol. Forecast. Soc. Change 78, 90–102. https://doi.org/10.1016/J.TECHFORE.2010.10.008.
de Jesus, A., Mendonça, S., 2018. Lost in transition? Drivers and barriers in the eco-innovation road to the circular economy. Ecol. Econ. 145, 75–89. https://doi.org/10.1016/j.ecolecon.2017.08.001.
Di Maio, F., Rem, P.C., Balde, K., Polder, M., 2017. Measuring resource efficiency and circular economy: a market value approach. Resour. Conserv. Recycl. 122, 163–171. https://doi.org/10.1016/j.resconrec.2017.02.009.
Dijkgraaf, E., Gradus, R., 2017. An EU recycling target: what does the Dutch evidence tell us? Environ. Resour. Econ. 68, 501–526. https://doi.org/10.1007/s10640-016-0027-1.
Circle Economy, Fabrications, TNO, Amsterdam, G, 2016. Circular Amsterdam. A vision and action agenda for the city and metropolitan area. In: Circular Cities Research Hub and Workshop at UCL.
Elia, V., Gnoni, M.G., Tornese, F., 2017. Measuring circular economy strategies through index methods: a critical analysis. J. Clean. Prod. 142, 2741–2751. https://doi.org/10.1016/j.jclepro.2016.10.196.
Ellen MacArthur Foundation, 2013. Towards the circular economy, 1. Ellen MacArthur Found, pp. 1–96. https://doi.org/10.1162/108819806775545321.
Eurostat, 2018. Municipal Waste Statistics. WWW Document]. URL. https://ec.europa.eu/eurostat/statistics-explained/index.php/Municipal_waste_statistics. accessed 4.22.19.
Fellner, J., Lederer, J., Scharff, C., Laner, D., 2017. Present potentials and limitations of a circular economy with respect to primary raw material demand. J. Ind. Ecol. 21, 494–496. https://doi.org/10.1111/jiec.12582.
Franco, M.A., 2017. Circular economy at the micro level: a dynamic view of incumbents' struggles and challenges in the textile industry. J. Clean. Prod. 168, 833–845. https://doi.org/10.1016/j.jclepro.2017.09.056.
Frantzeskaki, N., de Haan, H., 2009. Transitions: two steps from theory to policy. Futures 41, 593–606. https://doi.org/10.1016/J.FUTURES.2009.04.009.
Geels, F.W., 2011. The multi-level perspective on sustainability transitions: responses to seven criticisms. Environ. Innov. Soc. Transit 1, 24–40. https://doi.org/10.1016/J.EIST.2011.02.002.
Geissdoerfer, M., Savaget, P., Bocken, N.M.P., Hultink, E.J., 2017. The Circular Economy – a new sustainability paradigm? J. Clean. Prod. 143, 757–768. https://doi.org/10.1016/j.jclepro.2016.12.048.
Genovese, A., Acquaye, A.A., Figueroa, A., Koh, S.C.L., 2017. Sustainable supply chain management and the transition towards a circular economy: evidence and some applications. Omega 66, 344–357. https://doi.org/10.1016/J.OMEGA.2015.05.015.
Ghisellini, P., Cialani, C., Ulgiati, S., 2016. A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems. J. Clean. Prod. 114, 11–32. https://doi.org/10.1016/j.jclepro.2015.09.007.
Gregson, N., Crang, M., Fuller, S., Holmes, H., 2015. Interrogating the circular economy: the moral economy of resource recovery in the EU. Econ. Soc. 44, 218–243. https://doi.org/10.1080/03085147.2015.1013353.
Jabareen, Y.R., 2006. Sustainable urban forms: their typologies, models, and concepts. J. Plan. Educ. Res. 26, 38–52. https://doi.org/10.1177/0739456X05285119.
Jacobi, N., Haas, W., Wiedenhofer, D., Mayer, A., 2018. Providing an economy-wide monitoring framework for the circular economy in Austria: status quo and challenges. Resour. Conserv. Recycl. 137, 156–166. https://doi.org/10.1016/j.resconrec.2018.05.022.
Jacobsen, N.B., 2006. Industrial symbiosis in Kalundborg, Denmark. J. Ind. Ecol. 10, 239–255. https://doi.org/10.1162/108819806775545411.
Jordan, A.J., Lenschow, A., 2008. Innovation in Environmental Policy? Integrating the Environment for Sustainability. Edward Elgar Publishing Limited.
Kalmykova, Y., Rosado, L., 2015. Urban metabolism as framework for circular economy design for cities. In: Proc. World Resour. Forum 2015.
Kemp, R., Loorbach, D., 2003. Governance for Sustainability through Transition Management Paper for Open Meeting of the Human Dimensions of Global Environmental Change Research Community.
Kennedy, C., Pincetl, S., Bunje, P., 2011. The study of urban metabolism and its applications to urban planning and design. Environ. Pollut. 159, 1965–1973. https://doi.org/10.1016/J.ENVPOL.2010.10.022.
Kirchherr, J., Reike, D., Hekkert, M., 2017. Conceptualizing the circular economy: an analysis of 114 definitions. Resour. Conserv. Recycl. https://doi.org/10.1016/j.resconrec.2017.09.005.
Kirchherr, J., Piscicelli, L., Bour, R., Kostense-Smit, E., Muller, J., Huibrechtse-Truijens, A., Hekkert, M., 2018. Barriers to the circular economy: evidence from the European Union (EU). Ecol. Econ. 150, 264–272. https://doi.org/10.1016/j.ecolecon.2018.04.028.
Korhonen, J., Honkasalo, A., Seppälä, J., 2018a. Circular economy: the concept and its limitations. Ecol. Econ. 143, 37–46. https://doi.org/10.1016/j.ecolecon.2017.06.041.
Korhonen, J., Nuur, C., Feldmann, A., Birkie, S.E., 2018b. Circular economy as an essentially contested concept. J. Clean. Prod. 175, 544–552. https://doi.org/10.1016/j.jclepro.2017.12.111.
Koutamanis, A., van Reijn, B., van Bueren, E., 2018. Urban mining and buildings: a review of possibilities and limitations. Resour. Conserv. Recycl. 138, 32–39.

https://doi.org/10.1016/j.resconrec.2018.06.024.
Lieder, M., Rashid, A., 2016. Towards circular economy implementation: a comprehensive review in context of manufacturing industry. J. Clean. Prod. 115, 36–51. https://doi.org/10.1016/j.jclepro.2015.12.042.
Lüdeke-Freund, F., Gold, S., Bocken, N.M.P., 2018. A review and typology of circular economy business model patterns. J. Ind. Ecol. 00, 1–26. https://doi.org/10.1111/jiec.12763.
Makarichi, L., Techato, K.-A., Jutidamrongphan, W., 2018. Material flow analysis as a support tool for multi-criteria analysis in solid waste management decision-making. Resour. Conserv. Recycl. 139, 351–365. https://doi.org/10.1016/j.resconrec.2018.07.024.
MIE & MEA, 2016. A Circular Economy in the Netherlands by 2050 1–72.
Milios, L., 2018. Advancing to a Circular Economy: three essential ingredients for a comprehensive policy mix. Sustain. Sci. 13, 861–878. https://doi.org/10.1007/s11625-017-0502-9.
Mirata, M., Emtairah, T., 2005. Industrial symbiosis networks and the contribution to environmental innovation: the case of the Landskrona industrial symbiosis programme. J. Clean. Prod. 13 (10-11), 993–1002. https://doi.org/10.1016/j.jclepro.2004.12.010.
Ness, D., 2008. Sustainable urban infrastructure in China: towards a factor 10 improvement in resource productivity through integrated infrastructure systems. Int. J. Sustain. Dev. World Ecol. 15, 288–301. https://doi.org/10.3843/SusDev.15.4.
Park, J.Y., Chertow, M.R., 2014. Establishing and testing the "reuse potential" indicator for managing wastes as resources. J. Environ. Manag. 137, 45–53. https://doi.org/10.1016/j.jenvman.2013.11.053.
Pearce, D., Turner, K., 1990. Economics of Natural Resources and the Environment. Harvest. Wheatsheaf.
Petit-Boix, A., Leipold, S., 2018. Circular economy in cities: reviewing how environmental research aligns with local practices. J. Clean. Prod. 195, 1270–1281. https://doi.org/10.1016/j.jclepro.2018.05.281.
Prendeville, S., Cherim, E., Bocken, N., 2018. Circular cities: mapping six cities in transition. Environ. Innov. Soc. Transit 26, 171–194. https://doi.org/10.1016/j.eist.2017.03.002.
Ranta, V., Aarikka-Stenroos, L., Mäkinen, S.J., 2018. Creating value in the circular economy: a structured multiple-case analysis of business models. J. Clean. Prod. 201, 988–1000. https://doi.org/10.1016/j.jclepro.2018.08.072.
Rees, W.E., 1992. Ecological footprints and appropriated carrying capacity: what urban economics leveas out. Environ. Urbanization 4, 121–130. https://doi.org/10.1177/2455747117699722.
Reike, D., Vermeulen, W.J.V., Witjes, S., 2018. The circular economy: new or refurbished as CE 3.0? — exploring controversies in the conceptualization of the circular economy through a focus on history and resource value retention options. Resour. Conserv. Recycl. 135, 246–264. https://doi.org/10.1016/j.resconrec.2017.08.027.
Ribić, B., Voća, N., Ilakovac, B., 2017. Concept of sustainable waste management in the city of Zagreb: towards the implementation of circular economy approach. J. Air Waste Manag. Assoc. 67, 241–259. https://doi.org/10.1080/10962247.2016.1229700.
Rijkswaterstaat, 2018. Transitieagenda's: Op Weg Naar Een Circulaire Economie - Circulaire Economie Nederland [WWW Document]. URL. https://www.circulaireeconomienederland.nl/transitieagendas/default.aspx. (Accessed 10 December 2018).
Ritzén, S., Sandström, G.Ö., 2017. Barriers to the circular economy - integration of perspectives and domains. In: Procedia CIRP, pp. 7–12. In: https://doi.org/10.1016/j.procir.2017.03.005.
Rockström, J., Steffen, W., Noone, K., Persson, Å., Chapin III, F.S., Lambin, E.F., Lenton, T.M., Scheffer, M., Folke, C., Schellnhuber, H.J., Nykvist, B., de Wit, C.A., Hughes, T., van der Leeuw, S., Rodhe, H., Sörlin, S., Snyder, P.K., Costanza, R., Svedin, U., Falkenmark, M., Karlberg, L., Corell, R.W., Fabry, V.J., Hansen, J., Walker, B., Liverman, D., Richardson, K., Crutzen, P., Foley, J.A., others, 2009. A safe operating space for humanity. Nature 461, 472.
Roseland, M., 1997. Dimensions of the eco-city. Cities 14, 197–202. https://doi.org/10.1016/S0264-2751(97)00003-6.
Rotmans, J., Kemp, R., van Asselt, M., 2001. More evolution than revolution: transition management in public policy. Foresight 3, 15–31. https://doi.org/10.1108/14636680110803003.
Rouw, M., Worrell, E., 2011. Evaluating the impacts of packaging policy in The Netherlands. Resour. Conserv. Recycl. 55, 483–492. https://doi.org/10.1016/j.resconrec.2010.12.013.
Seeliger, L., Turok, I., 2013. Towards sustainable cities: extending resilience with insights from vulnerability and transition theory. Sustainability 5, 2108–2128. https://doi.org/10.3390/su5052108.
Stiles, W.A.V., Styles, D., Chapman, S.P., Esteves, S., Bywater, A., Melville, L., Silkina, A., Lupatsch, I., Fuentes Grünewald, C., Lovitt, R., Chaloner, T., Bull, A., Morris, C., Llewellyn, C.A., 2018. Using microalgae in the circular economy to valorise anaerobic digestate: challenges and opportunities. Bioresour. Technol. https://doi.org/10.1016/j.biortech.2018.07.100.
Tisserant, A., Pauliuk, S., Merciai, S., Schmidt, J., Fry, J., Wood, R., Tukker, A., 2017. Solid waste and the circular economy: a global analysis of waste treatment and waste footprints. J. Ind. Ecol. 21, 628–640. https://doi.org/10.1111/jiec.12562.
UN DESA, 2014. Urbanization Prospects.
UNEP, 2013. City-Level Decoupling: Urban Resource Flows and the Governance of Infrastructure Transitions. Summary for Policy Makers, 978-92-807-3298-6.
Urbinati, A., Chiaroni, D., Chiesa, V., 2017. Towards a new taxonomy of circular economy business models. J. Clean. Prod. 168, 487–498.
Utrecht, G., 2017. Raadsbrief Circulaire Economie.
Utrecht, G., 2018. Actieplan Maatschappelijk Verantwoord Inkopen Gemeente Utrecht Méér Maatschappelijke Èn Economische Waarde Voor Ons Geld.
van Buren, N., Demmers, M., van der Heijden, R., Witlox, F., 2016. Towards a circular economy: the role of Dutch logistics industries and governments. Sustainability 8, 647. https://doi.org/10.3390/su8070647.
Van Leeuwen, K., De Vries, E., Koop, S., Roest, K., 2018. The energy & raw materials factory: role and potential contribution to the circular economy of The Netherlands. Environ. Manag. 61, 786–795. https://doi.org/10.1007/s00267-018-0995-8.
Vellinga, P., Berhout, F., Gupta, J., 1998. Managing a Material World. Perspectives on Industrial Ecology. Academic Publishers, Dordrecht.
Venkata Mohan, S., Nikhil, G.N., Chiranjeevi, P., Nagendranatha Reddy, C., Rohit, M.V., Kumar, A.N., Sarkar, O., 2016. Waste biorefinery models towards sustainable circular bioeconomy: critical review and future perspectives. Bioresour. Technol. https://doi.org/10.1016/j.biortech.2016.03.130.
Wang, D., Li, J., Wang, Y., Wan, K., Song, X., Liu, Y., 2017. Comparing the vulnerability of different coal industrial symbiosis networks under economic fluctuations. J. Clean. Prod. 149, 636–652. https://doi.org/10.1016/j.jclepro.2017.02.137.
WFD 2018/851, 2018. WFD amendment 2018/851 [WWW document]. Off. J. Eur. Union. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.L_.2018.150.01.0109.01.ENG. (Accessed 12 March 2018).
Whalen, K.A., Milios, L., Nussholz, J., 2018. Bridging the gap: barriers and potential for scaling reuse practices in the Swedish ICT sector. Resour. Conserv. Recycl. 135, 123–131. https://doi.org/10.1016/j.resconrec.2017.07.029.
Wiedmann, T.O., Schandl, H., Lenzen, M., Moran, D., Suh, S., West, J., Kanemoto, K., 2015. The material footprint of nations. Proc. Natl. Acad. Sci. 112, 6271–6276. https://doi.org/10.1073/pnas.1220362110.
Yang, M., Smart, P., Kumar, M., Jolly, M., Evans, S., 2018. Product-service systems business models for circular supply chains. Prod. Plann. Contr. 29, 498–508. https://doi.org/10.1080/09537287.2018.1449247.
Zhijun, F., Nailing, Y., 2007. Putting a circular economy into practice in China. Sustain. Sci. https://doi.org/10.1007/s11625-006-0018-1.
Zink, T., Geyer, R., 2017. Circular economy rebound. J. Ind. Ecol. 21, 593–602. https://doi.org/10.1111/jiec.12545.