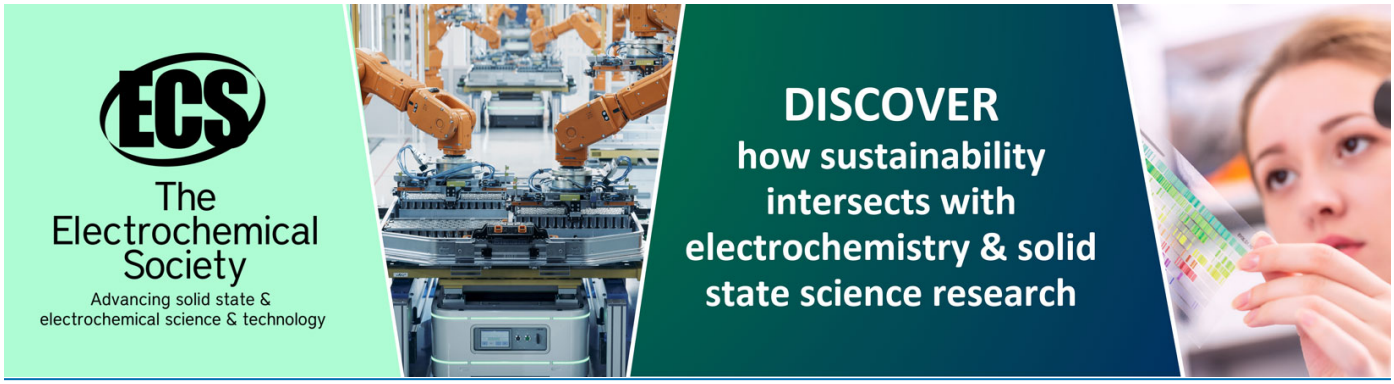
How close is the built environment to achieving circularity?



This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 642384.

How close is the built environment to achieving circularity?

August P. Nazareth

University of Bradford, Bradford, England

augustnazareth@gmail.com

Abstract. To accelerate the built environment and construction industry's uptake of the circular economy, we can begin by highlighting and publicising the construction industry's closest circular project examples that seem to (unintentionally) utilise recommended circularity principles and frameworks. The Ellen McArthur Foundation's (EMF's) Toolkit for Policy Makers has an easy-to-follow ReSOLVE (REgenerate, Share, Optimise, Loop, Virtualise, Exchange) framework. There are many initiatives in the construction industry to create less wasteful and operationally efficient building lifecycles including BREEAM, LEED, and LEAN etc. as well as design for manufacture and assembly (DfMA), offsite and modular, scan to BIM (Building Information Modelling), Internet of Things (IoT), Virtual Reality (VR), Virtual Design Construction and Digital Twins. In addition, with innovative technologies and digitalisation it is now possible to not only design new buildings with facilities management efficiencies in mind at the onset, but it is also possible to digitalise older and even heritage buildings, built hundreds of years ago. However, whether these initiatives are "circular", remains fragmented in an industry that is unfamiliar with the "circular economy". This paper will extrapolate the EMF's ReSOLVE frameworks through the context of three examples in vastly different formats; a desert lodge in the NamibRand Reserve (Namibia) close to achieving circularity; the tallest modular building in New York City that completely negates notions that pre-fab is undesirable and unattractive; and a large supermarket chain that has used BIM and other digitalisation to increase its operational efficiency, reduce material waste and increase visibility into space availability.

Keywords: Offsite construction, prefabrication modular, circular economy, ReSOLVE, building-as-a-service, digital twin.

1. The Circular Economy – a 1.8 trillion Euro opportunity for the EU

For construction firms that have only recently heard of the term 'circular economy' (CE) or have large customers in the built environment requesting a CE supply chain, this is a daunting challenge. How does a company fulfil a client's requirements when a) it does not understand what is involved b) what are the new processes c) what the technologies within the value or supply chain may be or d) how to deliver it? This is not uncommon according to a paper by Rizos, Behrens et al [1] and GreenEcoNet, out of 300 firms surveyed in France, Belgium, and England almost all respondents had not heard the term, nor its meaning. Similarly, in interviews conducted in two organisations with management functions such as

supply chain, production, sustainability, R&D, marketing, service and corporate social responsibility [2] it emerged that the sustainability teams had a very shallow understanding of the circular economy, if at all. Additionally, barriers to a deeper CE appeared around risk aversion to disruptive new business models, and attitudinal ideas as to which department was wholly responsible for initiating CE programs and tasks [2].

Today the circular economy is a large part of the European Union's (EU) 2030 action plan [3] to meet the United Nation's (UN) seventeen sustainability development goals [4], particularly around goal 12, ensuring sustainable consumption and production patterns. An update for 2018 [5] is an ambitious set of new circular economy measures, tools, timelines, and proposals. Yet, if market demand drives development then the CE is still very much in the infancy stage. Nonetheless, like transitions to Software as a Service (SaaS), cloud computing, mobile and social technologies, early adopters can gain competitive, first mover advantage in an industry that is poised for disruption. The Ellen MacArthur Foundation (EMF) states that "Shifting towards a growth within model would deliver better outcomes for the European economy and yield annual benefits of up to €1.8 trillion by 2030" [6].

2. Frameworks and Terminology

As a starting point in understanding the circular economy, its frameworks and terminology, this general review showcases some examples within the built environment that do not identify with being 'circular' and contrasts them alongside the EMF's ReSOLVE framework [7]. The intent is to provide a simplified understanding of how firms, when factoring their existing business models, BREEAM/LEED sustainability frameworks and/or CSR programmes, may be on the path to circularity. The three escalating examples were chosen by simple circularity around land, materials, people and business choices, leading to projects with a full stack of technology-based implementations that optimise operations of existing buildings and assets around circular principles. The paper concludes with two projects to benchmark against showing what circularity looks like when whole system design is planned for by ownership, and constructed and furnished with circular economy principles at the outset, then followed through within the supply chain, operations and facilities management.

We begin with a high-level description of the ReSOLVE framework which is incorporated in the Ellen MacArthur Foundation's *Delivering the Circular Economy: A toolkit for policymakers* [7]

2.1. The Circular Economy – Waste equals food for the next process

The circular economy (Figure 1) is a restorative and regenerative industrial system that creates multiple value and growth opportunities, decoupled from finite resource consumption and derived from existing economic structures, materials and products [6].

> "*Businesses throw away hundreds of billions worth of valuable materials because they are not designed for recovery. What is gained on the front end through convenient bonding is lost on the back end through destructive mixing of materials that degrades their quality*."
> (Mulhall and Braungart 2013: 76) [8]

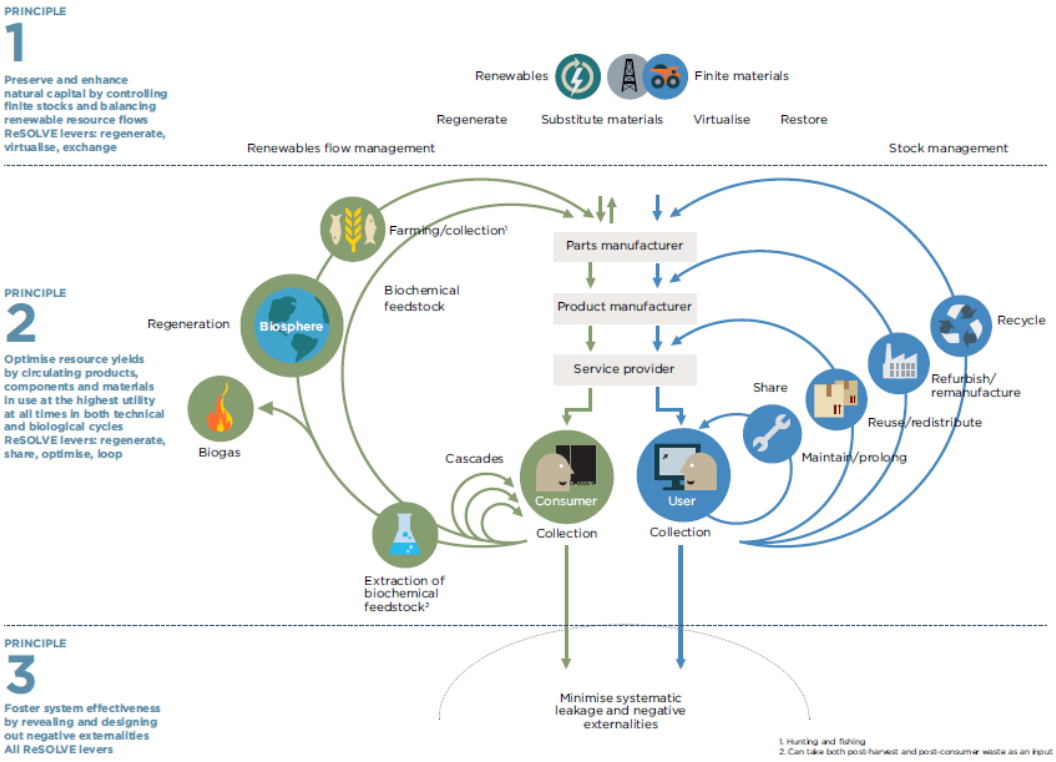


Figure 1. Butterfly diagram for biomaterials and technical materials.

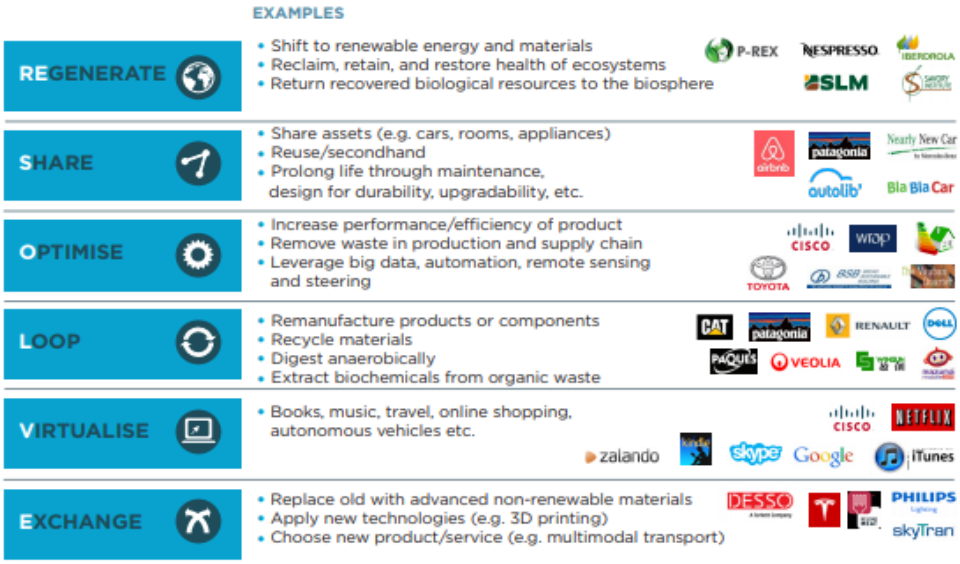


Figure 2. Companies committed to the circular economy [7]

3. Case 1: The ReSOLVE framework and the EcoTourism Framework

The International Ecotourism Society (TIES) defines the ecotourism framework as "responsible travel to natural areas that conserves the environment, sustains the well-being of the local people, and involves interpretation and education" [9]. In the 25 years since its existence it has further refined its responsibility to include three additional principles that ecotourism is 1) non-consumptive and non-

extractive 2) creates an ecological conscience and 3) holds eco-centric values and ethics in relation to nature [9].

3.1. Wolwedans, Namibia

The alignment between the circular economy and ecotourism is visible at Wolwedans [10], a tourist destination in Namibia that holds Global Ecosphere Retreat® (GER) certification from The Long Run as a centre of excellence in sustainable tourism and the well-being of people.

3.2. Natural and social capital result in revenue generation - REGENERATE

After decades of unsustainable cattle and sheep farming and large-scale hunting [10] led to soil and ecosystem degradation, the NamibRand Nature Reserve in Namibia was created by landowners for land conservation. Today, the 200,000ha reserve is self-sustaining through high quality, low-impact tourism with only 4 other properties leading to the regeneration, bio-diversity and resilience of the reserve.

3.3. Building construction - OPTIMISE / LOOP / EXCHANGE/ REGENERATE

Wolwedan's collection of camps and lodges total only 44 beds, see about 9000 visitors per year and are designed for minimal environmental impact by utilising simple, non-toxic materials in its re-usable, reversible and modular construction [10]. The camps/lodges can be dismantled, quickly returning the environment to its original state. Solar powers all lighting and hot water requirements.

3.4. Operations – REGENERATE / SHARE / OPTIMISE / LOOP / EXCHANGE

All Wolwedan's camps are serviced by a shared centralised basecamp and infrastructure, consisting of a sophisticated water pump house and filtration system [10], central office, stores and inventory, staff housing and a staff training academy [10], etc. Additionally, each operation feeds another; the remote and unforgiving desert landscape necessitates a circular exchange of regenerating and optimising activities detailed below:

3.4.1. ReSOLVE framework indicators.

1. Close monitoring and zero tolerance policy to water wastage [10], Grey water is collected for the property's minimal planting.
2. As delivery from the nearest city is infrequent, bulk purchases reduce all packaging; it's often re-used for other purposes or sent for recycling, utilizing the empty truck return.
3. The solar powered rooms are not equipped with coffee makers with hard-to-recycle pods, instead resilient steel thermos flasks are used. Overall, disposable single-use plastics, coffee pods, paper or bags were not in evidence.
4. Furniture is made/refurbished onsite utilising combinations of new/salvaged pieces of broken decking or furniture shared amongst the camps and re-used to make new iterations (conversation with staff).
5. Guest and staff food waste/scraps are consumed by resident pigs or composted – completing the food/ waste loop.
6. Shared based camp parking and efficient loading of trips reduces stress on the landscape leading to each camp.
7. A greenhouse provides fresh vegetables and salad greens that make up the menus for guests and the staff – reducing the energy and pollution of truck deliveries more than once a week from Windhoek (5 hours away)
8. People – the onsite academy [10] trains and houses staff, providing social capital and new career opportunities in this remote area, creating a symbiotic exchange of benefits for all. In addition, the company has reverse integration into Namibia Institute of Culinary Education (NICE), a training school and restaurant in Windhoek serving itself and the wider community of tourist establishments.

3.5. Wolwedans - High level circularity ReSOL_E in its building construction, operations and facilities management

The above is a high-level evaluation from available sources online, base camp tour and staff interviews during a visit to Wolwedans in 2018. Observable improvements in achieving a deeper circular model include re-fillable shampoo bottles, re-usable glass water bottles at meals, or other mitigation straight from the tap. Wolwedans may have virtualised in some areas, but this is unknown at writing. Deeper circularity review would entail reviewing the entire supply chain for wood, paints and varnishes, canvas, bedding, to embed cradle to cradle systems, take-back and reverse logistics, etc.

Overall, Wolwedans' ownership and responsibility to land, people, business and operations affords a long-term strategy that pays equal, holistic attention to all the components that make up the business and duty of care and a direct contrast to a fragmented, outdated take-make-dispose linear model.

4. Case 2: The ReSOLVE framework - urban mixed-use high-density development

Often buildings are designed and constructed in silos that separate the owner/employer, design, engineering, and construction, with less attention to asset operations, maintenance and longevity of the building. While there is significant data, it is fragmented and disparate. The UK government's series of PAS documents [11] and frameworks (mandated in 2016) attempts to establish collaborative working and information requirements for the construction (CAPEX) and operational (OPEX) phases with facilities management in the building lifecycle.

This contrasts with Wolwedans' case, where stakeholders that own the land, the business, also operate the facilities and have a deeply vested interest in the entire building lifecycle.

4.1. 461 Dean Street - The ReSOLVE Framework and Design for Manufacture and Assembly (DfMA), (offsite and modular construction)

461 Dean Street, a rental building in Brooklyn, NY with LEED Silver certification, still holds the title of tallest modular building [12,13] and built for developers, Forest City Ratner [14] (acquired by Brookfield in 2018). This case study employs many of the circular economy principles [6] of systems re-thinking and a holistic collaboration between the developer, architects, the community, and project trades men and women.

4.2. New business model – OPTIMISE / VIRTUALISE / EXCHANGE

After the downturn in 2008/9 and recurring issues with construction, FCR [14] re-evaluated their approach to the project: A newly created company, FCS Modular [15], would oversee construction using prefab modules, accelerating time to market [14], reducing onsite waste, and project and budget over-runs. FCS was strategically located in a nearby warehouse at the Brooklyn Navy Yard to reduce transportation to/from the building site of the assembled modules. Additionally, the modules would be shipped at night [14] avoiding community disruption.

4.3. Community and social capital – REGENERATE / SHARE / OPTIMISE / EXCHANGE

Non-jurisdictional union workers would assemble about 930 modules, resulting in 363 apartments and offering 23 different layouts for studios, 1- and 2-bedroom configurations [12]. The high-quality building promotes compact urban growth in an integrated high density urban, mixed-use development with approximately 50% of units shared with mid-to-low income housing, regenerating a once declining neighbourhood. Upon opening, 84,000 New Yorkers applied to live there [12]. High-quality construction also prevents decay or 'undesirability' of the building over time.

"One of the biggest hurdles with prefab isn't just structural integrity or waterproofing, but the workers themselves: Prefab has long been perceived as a way for developers to avoid paying construction workers and, thus, to bypass unions altogether. So, one of FCS's biggest successes has actually been a legal one: The formation of a new, non-jurisdictional "Modular Division, "made up of union carpenters, iron workers, painters, plumbers, electricians, and more. It's this agreement that

makes it possible to use 100 percent union labour at the Navy Yard site, where small teams from each trade work on assembling each module simultaneously." [16]

4.4. The construction process – SHARE / OPTIMISE / LOOP / VIRTUALISE / EXCHANGE
Efficiently mapping systems in a clean dry environment - all the modules start off as steel boxes and become apartments in less than a week following choreographed scheduling; further simplified by using manufacturing drawings versus construction drawings [17] by different teams. Known material requirements guarantee they'll fit the first time (unlike in the linear version) [16], keeping production predicable and cost efficiently reducing waste. Turner Construction, as contractors, used LEAN frameworks for pre-planned optimised activities including module and material delivery, staging and installation, effectively integrating two parallel tracks (onsite/offsite) reducing time-to-market.

4.4.1. 461 Dean Street - high level circularity elements towards ReSOLVE framework with immense opportunities for asset owners, construction, suppliers and manufacturers.
This type of building has a great framework for achieving full circularity or cradle to cradle approaches in the next design iteration, especially since LEAN process and LEED certification frameworks are in place. Being modular, disassembly is already possible for long term adaptability and end-of-life strategies if it included reusable materials [18,19], material passports and associated take-back systems by the suppliers of the facades, windows, etc. [18].

New business models are emerging linking closed loop material control around leasing, performance and take-back programs [20,21] under product-service systems, reverse logistics, new alliances, appliance-as-a-service [21,22] lighting-as-a-service [21,23]), that will bring the circular economy to scale within the building industry and supply chain, making building-as-a-service possible. All these models impact the supply chain within the built environment and are a strategic opportunity [19] for early adopters. For asset owners/rental buildings, these business models offers flexibility, adaptability and an opportunity to decrease ownership of elements that perhaps do not actually belong within the building-as-a-service value chain, and which degrade without end-of-life recourse once the asset owner has possession.

5. Case 3: The ReSOLVE framework and multi-location retailers with existing assets

Supermarket chains like Sainsbury's (number two in the UK with over 16% market share) represent massive opportunities to generate part of the circular economy's 1.8 trillion-euro opportunity projected by the EMF [6] by utilising combinations of older technologies such as laser scanning with new three-dimensional (3D) design and data collection processes like Building Information Modelling (BIM) [24].

Today it is possible to laser scan a 300-year-old heritage building like St. James Church, London and convert the 'as-built' images into 3D models. The 3D model combined with BIM [24,25], creates an Asset Information Model [26] and is effective when used for facilities management (FM), repair and maintenance, and a database of all interior/exterior components [26]. The business context should drive decisions on whether to create 3D/BIM models of every existing asset in a portfolio, or to collect existing information on each asset and digitise for data extraction.

5.1. Sainsbury's digital estate – SHARE / OPTIMISE / VIRTUALISE / EXCHANGE
In Sainsbury's case, with a channel of 2800 stores [27] including convenience, Argos, and Habitat, the supermarket is already on the path to creating its digital estate. Due to the sheer number of assets (not including warehouses and back of business assets) and simplicity of the structures, instead of laser scanning all the stores, converting them into 3D models, *then* extracting the information in a lengthy series of steps, Sainsbury's opted to digitise the information they *already had,* utilising existing legacy systems, 2D drawings, etc. using BIM standards. The data is now available programmatically in a Common Data Environment (CDE). A Sainsbury's youtube.com video on *Building and Maintaining a Digital Estate* shows the path to achieving 'one property' that make up their digital estate. In a recent conversation with their Systems Development Manager, the one property digitalisation initiative has

uncovered unused shadow space to the tune of 20% on a macro level. Thus, adding a concession or making other strategic decisions coincides with an environment-saving impact to optimise existing buildings.

5.2. ReSOLVE opportunities for Sainsbury's and large asset owners to transition to circular economy through digital twins

For Sainsbury's, while not done specifically for the CE, aggregation of information and transparency can highlight where duplicated micro assets, counters, endcaps, etc. reside and where economies of scale emerge for higher asset utilisation. In a hypercompetitive sector, virtualising provides a holistic view that can result in business strategies in forward or reverse integration, diversification into new formats or simply looking at the value chain with a new lens for competitive advantage; like supermarket-as-a-service and result in new CE value creation models.

And like jet engines/power plants with 'digital twins' [28], once digitised information and 3D models are available, future construction optimisation strategies can contribute to the transition to the circular economy. Consider the performance, exchange or sharing opportunities represented by a (once mute) large office building or mixed-use development with its digital twin utilising Internet of Things (IoT) sensors consistently 'reporting back' [29] and providing a profile of historical and real-time behaviour [30]. For instance, when the combined data from several assets are aggregated, emerging patterns of usage, footfall, temperatures, and collections of interior assets can lead to reconfigured workforce patterns and reduced energy consumption; whilst other trends and anomalies become a source for predictive just-in-time maintenance versus just-in-case *costly* maintenance, or break/fix disaster maintenance. This is reflective of the ReSOLVE framework.

6. Conclusion - Recommended interventions and entry to the circular economy

The preceding examples highlight just a few contextual transitional pathways and intervention points for stakeholders not only in construction, but the entire built environment supply chain, including asset owners. A transformational internal business process might look like any other – 1) secure executive commitment/sponsorship, budget and task group 2) ensure understanding of CE 3) conduct PESTLE/SWOT analysis for market gaps/goal identification and align with capabilities and business strategy 4) identify low hanging fruit for early (and easy) wins building commitment internally/externally 5) CE programme integration that is reviewed, measured, revised and reported on 6) publicise efforts through marketing, networks and partnerships. Further, conducting a light audit or benchmarking exercise against built-for-purpose circular designed projects provides greater clarity and signposting to circularity such as 1) Circl, a new pavilion in Amsterdam completed in September 2017 [21,31] and 2) Dutch Mountains [32,33] that begins construction in 2019. In both projects, note the major shift in value alignment, resource decoupling, lack of silos and barriers at the onset, while still generating revenue. The asset owners/operators, suppliers, construction, high tech partners, etc. all share commitment to changing current linear take-make-dispose business models to symbiotic relationships between people, environment, business and operations, similar to Wolwedans's.

In closing, ReSOLVE and the circular economy's terminology may be unfamiliar, however, as illustrated, many elements already exist in practice such as BREEAM, LEED and other certifications and frameworks. The main takeaway from this review (for all stakeholders), is understanding that the CE is a whole-systems proposition resulting in *no waste left behind* in a building lifecycle, including end-of-life, and goes beyond sustainability and recycling measures. Recommended interventions should occur first where impacts are greatest/easiest (and fastest) depending *contextually* on each firm's process, organisation and clients. Further, with more and more attention, policy change/taxation, as well as available funding in the UK/ EU, partnering with consultancies, universities and MBA-level CE professionals will accelerate the transition through factual and authentic whole-system design, models and practices. For the 'business as usual' construction firm, the impetus and call for 'disruption' is every day news in the UK, EU and USA. *The circular economy **is** that disruption, while delivering greater profitability and social responsibility.*

7. References

[1] Rizos V, Behrens A, Kafyeke T and Hirschnitz-Garbers, M Ioannou A 2015 The Circular Economy: Barriers and Opportunities for SMES
[2] Ritzén S and Sandström G Ö 2017 Barriers to the circular economy – Integration of perspectives and domains Procedia CIRP 64 7–12
[3] EUR-LEX 2015 Closing the loop - An EU action plan for the circular economy
[4] UN The sustainable development agenda
[5] EU Commission 2018 Circular economy strategy - environment - European Commission
[6] Macarthur E 2015 Growth within: A circular economy vision for a competitive europe Ellen MacArthur Found. 100
[7] Ellen MacArthur Foundation 2015 Delivering the circular economy: A toolkit for policymakers
[8] Mulhall D and Braungart M 2013 Cradle-to-cradle: From recycling building components to upcycling buildings. Adapting to accelerating building cycles. A New Dynamic: Effective Business in a Circular Economy ed K Webster, J Blériot and C Johnson (Ellen MacArthur Foundation)
[9] TIES 2015 TIES announces ecotourism principles revision
[10] Swart C 2012 Wolwedans Sustainability
[11] GOV UK 2013 A new era for digital technologies helping to reform the construction industry
[12] Garfield L 2016 Inside 461 Dean, New York City's new modular apartment building Business Insider
[13] The Skyscraper Center 2018 461 Dean
[14] Austermann A 2015 461 Dean street factory tour | CTBUH New York 2015
[15] Speiser M 2018 Inside the Brooklyn factory building stackable homes - Technical.ly Brooklyn Technical.ly
[16] Campbell-Dollaghan K and Stango N 2013 Inside the NYC super-factory building America's tallest prefab tower
[17] Bates T 2015 We don't actually use construction drawings... TheBIMhub
[18] BAMB 2018 Materials passports: Optimising value recovery from materials
[19] WMW 2018 Continuus material recovery acquires rewall to meet rising demand
[20] Commercial Carpets 2018 Cradle to cradle
[21] ABN-AMRO 2017 A Future-Proof Built Environment
[22] Bundles 2018 Bundles | How it started
[23] Philips.com 2015 Philips provides Light as a Service to Schiphol Airport
[24] Bernstein P 2015 The Future of Making Buildings
[25] Mills F 2017 What is "Scan to BIM"?
[26] Adán A, Quintana B, Prieto S A and Bosché F 2018 Scan-to-BIM for 'secondary' building components Adv. Eng. Informatics 37 119–38
[27] J Sainsbury plc 2018 Annual Report and Financial Statements
[28] General Electric 2016 GE Digital Twin: Analytic Engine for the Digital Power Plant
[29] Datta S P A 2017 Emergence of digital twins - Is this the march of reason? J. Innov. Manag. 5 14–33
[30] Deloitte University Press 2017 Industry 4.0 and the digital twin
[31] Circl.nl 2017 The making of Circl
[32] Bloc 2018 The Dutch Mountains - BLOC
[33] The Dutch Mountains 2018 Smart, circular and high-tech

Acknowledgments
Case study information are from publicly available sources/videos online. Informal conversations with staff and basecamp visit at Wolwedans in 2018. Informal conversations with Sainsbury's Systems Development Manager during Digital Construction Week, 17 October, 2018. Extracts: author's unpublished paper "From Linear to Circular – Can the Building and Construction Sector Run on Circles?"