London Waste and Recycling Board (LWARB)

Circular Economy Effects on Waste Production in London

Impact Assessment Report

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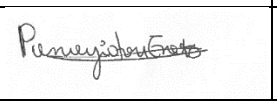
		Signature			
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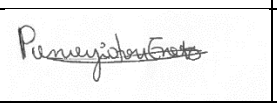
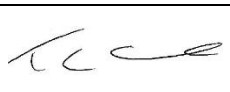
		Signature			
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Abbreviations

Abbreviation	Meaning
AM	Additive manufacturing
Arup	Ove Arup & Partners Limited
BIM	Building Information Modelling
Capex	Capital expenditure
CDEW	Construction, demolition and excavation waste
CE	Circular Economy
C&IW	Commercial and industrial waste
CMMS	Computerised maintenance management system
CSA	Community Supported Agriculture
Defra	Department for Environment, Food & Rural Affairs
DMC	Domestic Material Consumption
EEE	Electrical and Electronic Equipment
EU	European Union
FALP	Further alterations to the London Plan
GLA	Greater London Authority
HW	Household waste
IoT	Internet of Things
KPV	*Komunalno Podjetje Vrhnika*
LACW	Local authority collected waste
LWARB	London Waste and Recycling Board
MRO	Maintenance, repairs, operation
Opex	Operational expenditure
PSS	Product-service system
PVC	Polyvinyl chloride
RCV	Refuse collection vehicle
ROAR	Robot-based autonomous refuse
SLS	Selective laser sintering
VDC	Virtual Design and Construction
WEEE	Waste electrical and electronic equipment
WRAP	Waste and Resources Action Programme

1 Introduction

1.1 Overview

Ove Arup & Partners Limited (Arup) has been appointed by the London Waste and Recycling Board (LWARB) to assess the impact of the transition to a Circular Economy on the waste quantities projected to arise in London during the period 2016 to 2041.

This work aims to inform the development of the next London Plan being prepared by the Greater London Authority (GLA) on behalf of the London Mayor, as the estimation of waste arisings will dictate the allocations of land local planning authorities (i.e. the London Boroughs) must make for waste management activities.

1.2 The circular economy

The Circular Economy (CE), as illustrated in **Figure 1**, provides a means of retaining resource within the economic cycle and delaying the point at which the resource is discarded and thus becomes waste.

The circular economy aims to decouple economic growth from resource consumption. It is restorative and regenerative by design, and aims to keep materials, products and components in repetitive technical and biological loops, maintaining them at their highest utility and value at all times. This requires technical, organisational and behavioural change.

The present study excludes any CE initiatives that involve the flow of waste and recyclables. In other words, it only aims to assess initiatives that fall up to the 'sharing' and maintain/prolong sections of the 'technical cycles' and inner cascades of the 'biological cycles' (e.g. sharing of food) of the CE butterfly diagram shown in **Figure 1**.

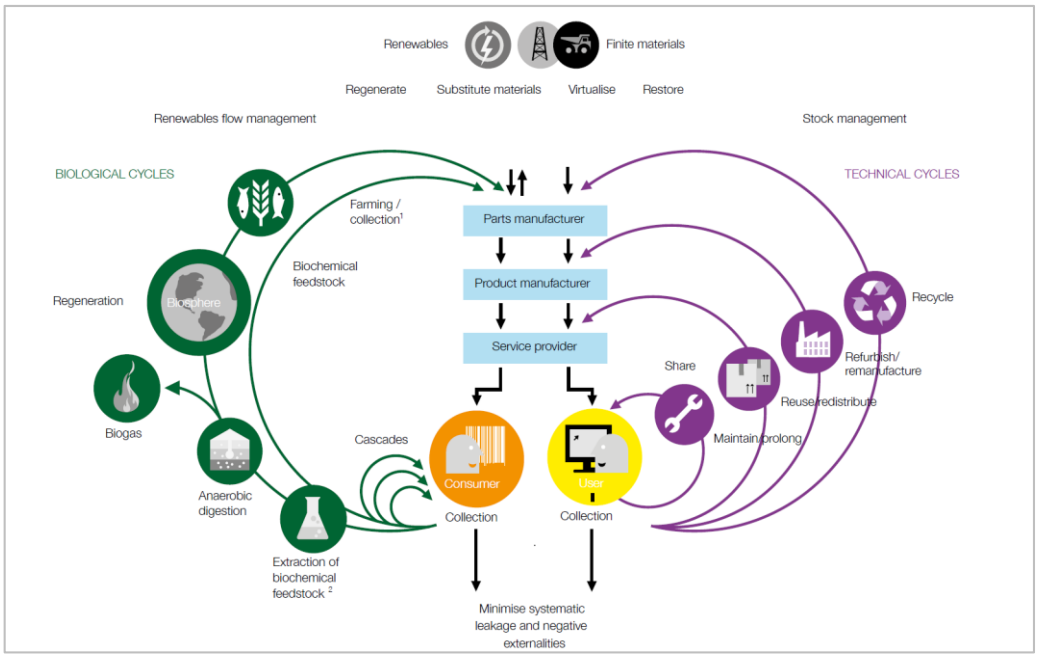

Figure 1: The circular economy[1]

The transition from a 'linear economy' to a 'circular economy' model will have an impact on the type and quantity of waste operations and treatment infrastructure required in London. Therefore, the adoption of CE within London, has implications for future land-use.

A strong focus on waste reduction throughout London, can free up certain waste storage and waste treatment sites, which, if safeguarded, can be used in the future to accommodate the infrastructure required to facilitate the uptake of a number of other CE initiatives that fall within the green and purple 'wings' of the CE butterfly diagram (see **Figure 1**). In other words, there will be land available to site CE technologies, processes and services that reuse, recycle, and treat waste, which will allow the creation of a more efficient, higher performance economy.

[1] Adapted from Ellen MacArthur Foundation and McKinsey Center for Business and Environment; Adapted from Braungart & McDonough, Cradle to Cradle (C2C).

2 Scope of work

The scope of work for this study was agreed at a meeting with LWARB on 15 March 2017. It covers the following work tasks:

- Identification of CE initiatives that have the potential to reduce waste arisings, with specific reference to the three waste types in the updated, unpublished waste arisings projection model for the London Plan, prepared by SLR Consulting Limited ('the updated GLA model') (including Construction, Demolition and Excavation Waste (CDEW), Commercial and Industrial Waste (C&IW), and Household Waste (HW);
- Quantification of the waste reduction potential of the identified CE initiatives on the waste arisings of the three waste types in the updated GLA model under three different CE scenarios (low CE uptake, medium CE uptake, high CE uptake);
- Identification of the relationship of the uptake of each CE scenario with time; and
- Sensitivity testing of each scenario by applying it to the latest revision of the updated GLA model and determination of the potential of reducing waste.

All chosen CE initiatives address some or all of the five areas of focus identified by LWARB in 'London the Circular Economy Capital' report[2], including:

- Built environment;
- Food;
- Textiles;
- Electricals; and
- Plastics.

All CE initiatives incorporate and/or directly address the following cross-cutting themes identified by LWARB[3]:

- Communications;
- Collaboration;
- Policy;
- Procurement and market development;
- Finance;
- Business support;

[2] London Waste and Recycling Board (2015), *Towards a circular economy – context and opportunities;* Available at: http://www.lwarb.gov.uk/wp-content/uploads/2015/12/LWARB-circular-economy-report_web_09.12.15.pdf (Accessed 8 March 2017).
[3] Ibid.

- Demonstration (note: this is not directly addressed, but the CE initiatives below can demonstrate to others their benefits, resulting in a wider adoption in the future); and
- Innovation.

As the aim of this study was to assess the waste reduction potential of CE initiatives, only those CE technologies, processes and services that can achieve waste reduction (i.e. waste prevention) were used in the assessment, as opposed to those CE initiatives addressing any other stage of the waste hierarchy (e.g. preparing for reuse and recycling) (see **Figure 2**).

The Department for Environment, Food & Rural Affairs (Defra) states that: *'a material is considered to be waste when the producer or holder discards it, intends to discard it, or is required to discard it'*[4]. Whilst acknowledging the legal definition of waste, this study has treated any materials that are considered 'surplus' by their owners/users and which can be given to other users without any alterations (i.e. not needing preparation before being reused), as not being waste.

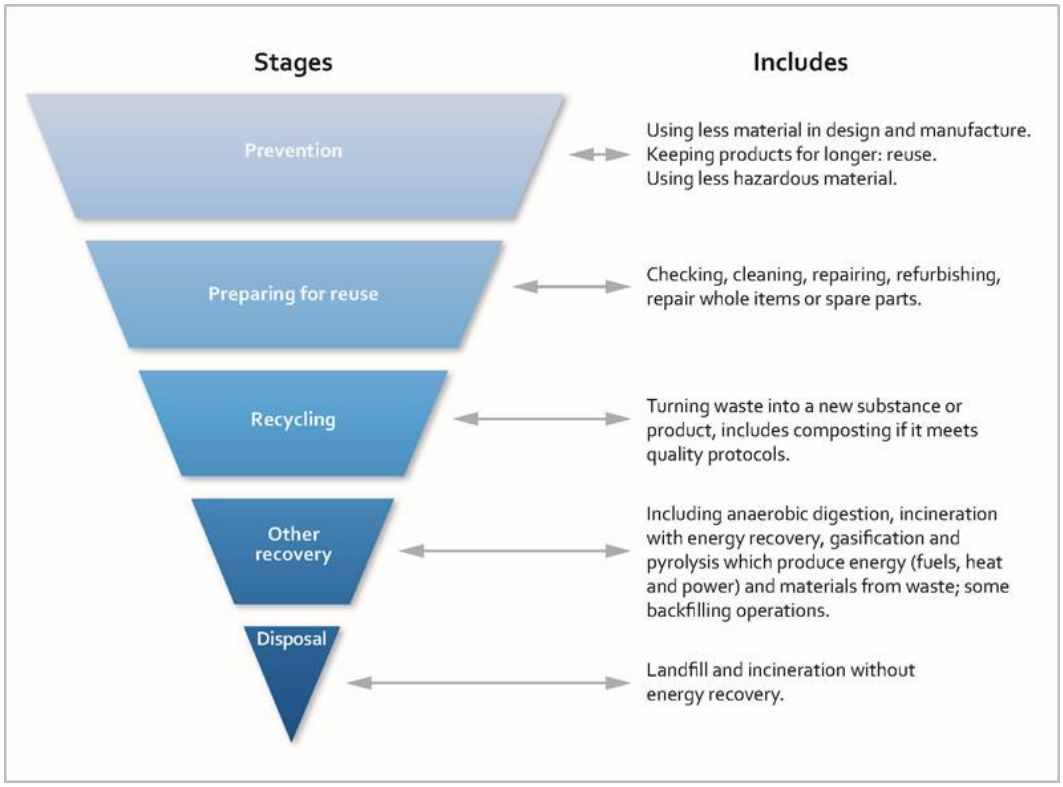

Figure 2: The waste hierarchy

[4] Defra (2016), *Decide if a material is waste or not: general guide;* Available at: https://www.gov.uk/government/publications/legal-definition-of-waste-guidance/decide-if-a-material-is-waste-or-not (Accessed 3 April 2017).

'Uptake' refers to the level at which each CE initiative is adopted by local authorities, commercial businesses and individuals. In other words, it refers to the popularity of a CE initiative and the extent at which it can be considered mainstream.

3 Methodology

3.1 Summary

The methodology that was carried out in order to establish the effects of CE on CDEW, C&IW and HW arisings across London is summarised in **Figure 3** and it is explained in greater detail below.

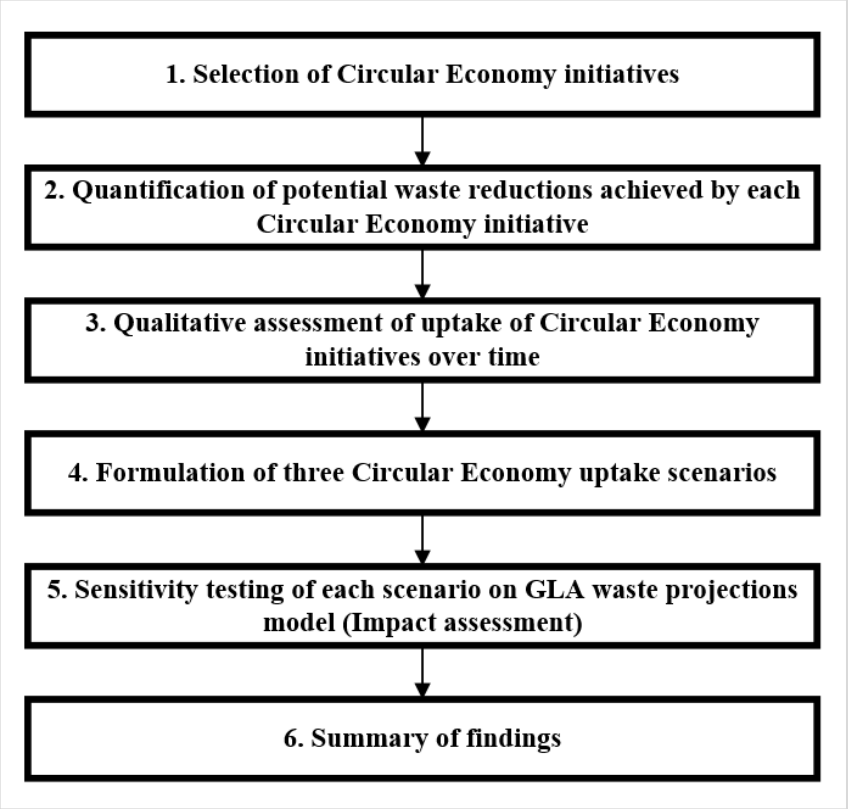

Figure 3: Methodology summary

3.2 CE initiatives

3.2.1 Overview

Nine CE initiatives were selected, all of which have the potential to achieve waste reduction. Each one of the nine CE initiatives has been proven to be feasible in financial, social and environmental terms, and has already been tried and tested in some parts of the world.

As, in many cases, these CE initiatives involve and/or target the same business sectors and/or the same types of materials and waste, they can be adopted in combination in major urban areas, like London, in order to achieve significant synergistic effects, as shown in **Figure 4**.

Section 3.2 provides an introduction to each of the nine CE initiatives, explaining their relevance, importance and contribution to waste reduction.

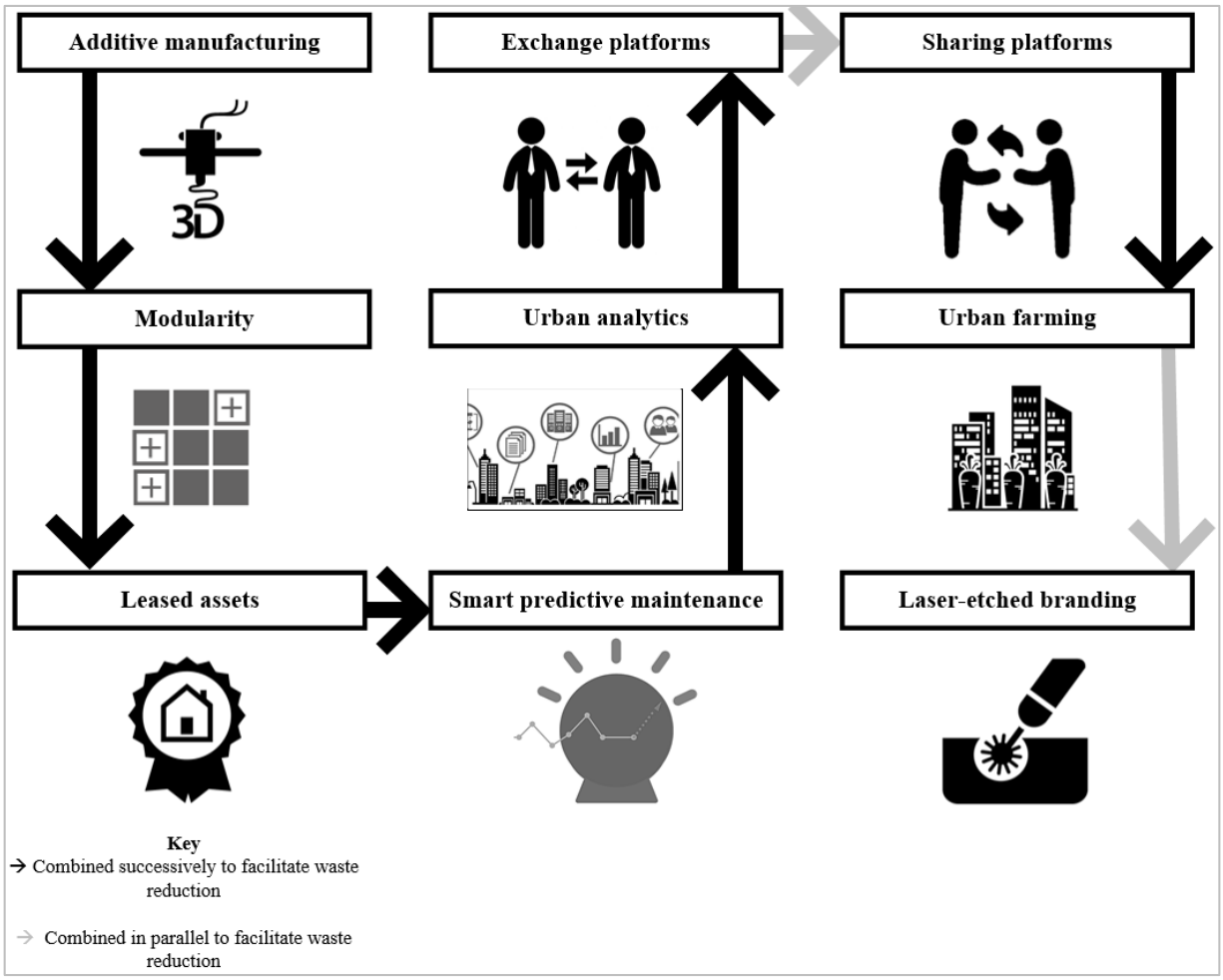

Figure 4: The selected CE initiatives

3.2.2 Additive manufacturing

Additive manufacturing (AM), also known as 3D printing, is achieved by various technologies that construct an object layer by layer. AM can be used by the construction industry in order to achieve reductions in construction material wastage, as lighter, cost-effective materials can be produced.

Biodegradable materials are widely used within 3D printing communities by developers and material suppliers for use in many applications. Currently a wide range of materials, such as bio-plastics, wax, organic materials and food are available and typically developed for use in fused deposition modelling, material extrusion or selective laser sintering (SLS) 3D printing technologies.

The additive nature of the process means that less waste material is created, as components can be designed to be fit for purpose, and this provides cost savings on material inputs. Producing goods on demand through AM also reduces inventories and the risks associated with oversupply and obsolescence[5].

[5] PwC (2015), *Turning additive manufacturing into business;* Available at: https://www.pwc.nl/en/assets/documents/pwc-turning-additive-manufacturing-into-business.pdf (Accessed 23 March 2017).

It has been proven that AM can be used to construct entire apartment blocks, as was recently done in China, where a five-storey building was designed and 3D printed by WinSun[6], using recycled concrete (see **Figure 5**).

Figure 5: 3D printed building in China (Source: Winsun[7])

Targeted LWARB focus areas (and estimated level of impact on them)

- Built Environment (medium-high); and
- Plastics (medium-high).

3.2.3 Modularity

Designing buildings and structures in modules allows component modules to be added, removed or replaced as required (see **Figure 6**).

Modular construction involves the use of factory-produced pre-engineered building units that are delivered to site and assembled as large volumetric components or as substantial elements of a building. More than 60% of the construction can be completed off-site before being transported to the site as pre-fabricated modules. Modules are often delivered fully fitted, and the cladding and

[6] Starr, M (2015), *World's first 3D-printed apartment building constructed in China;* Available at: https://www.cnet.com/news/worlds-first-3d-printed-apartment-building-constructed-in-china/ (Accessed 23 March 2017).
[7] Winsun (2014), *3D House Tech*, Available at: http://www.yhbm.com/index.php?m=content&c=index&a=show&catid=68&id=68 (Accessed 3 April 2017).

roof structure may be attached directly to the framework of the modules, which reduces the cost of a secondary cladding support structure.

Pre-fabrication in a factory environment was shown to be able to achieve reduce wastage, compared to the traditional cast in-situ construction method[8]. In terms of waste generation, prefabrication can achieve waste reductions of up to 80% in materials such as timber and concrete[9].
Modular design can also be applied to the fabrication of textiles. A good example is carpets. If carpet tiles are designed in a modular way, with random patterns mimicking natural patterns (e.g. fallen leaves), they can reduce wastage, while they can also be easily replaced if damaged[10].

Figure 6: Modular building construction in Manchester (Source: dezeen[11])

Targeted LWARB focus areas (and level of impact on them)

- Built environment (high); and
- Textiles (low-medium).

3.2.4 Leased assets

The idea of the leasing society is strongly connected with the concept of 'Product-Service Systems' (PSS). Here the emphasis is on the 'sale of use' rather than the 'sale of product'. The customer pays for using an asset, rather than its purchase,

[8] Lu and Yuan (2013), *Investigating waste reduction potential in the upstream processes of offshore prefabrication construction*, Renewable and Sustainable Energy Reviews: 28, 804-811
[9] Tam *et al* (2007), *Towards adoption of prefabrication in construction*, Building and Environment: 42, 3642-3654
[10] WRAP (2012), *Delivering closed loop carpet manufacturing processes;* Available at: http://www.wrap.org.uk/sites/files/wrap/InterfaceFLOR%20WRAP%20case%20study%20FINAL.pdf (Accessed 15 March 2017).
[11] Dezeen (2016), ShedKM and Urban Splash let residents design layouts for modular Manchester homes, Available at: https://www.dezeen.com/2016/03/09/house-shedkm-urban-splash-modular-homes-architecture-manchester-england/ (Accessed 12 April 2017).

and so benefits from a restructuring of the risks, responsibilities, and costs traditionally associated with ownership.

The leasing business model has traditionally been employed for its reduced capital investment. Now the resource efficiency benefits can be seen with the owner of the asset retaining responsibility for it throughout its lifecycle with the asset returned back to the owner at the end of its useful life where it can be more easily repaired, reused and recycled. Leasing assets promotes designing products that can be easily maintained and repaired so that their useful life can be extended.

Some leasing models that can be used by businesses and/or householders in the UK to achieve waste reduction include:

1. Façade leasing – this business model is based on performance based contracts which can facilitate the rate and depth of energy renovations in buildings. Façade leasing can drastically increase the rate of energy-efficient building renovations by decreasing their initial investment requirements, optimising stakeholder returns, and spreading the risks, instead of concentrating them on one stakeholder[12];
2. Selling resource management instead of waste disposal – this business model involves the investment in applying resource management expertise throughout a manufacturing system, instead of relying on the identification of a suitable contractor to dispose of the waste at the end of the manufacturing process[13];
3. Chemical leasing – this business model is based on the collaboration between two or more industrial partners, where one uses the chemical and the other provides their service, so that environmental impacts and use of hazardous chemicals are reduced[14];
4. Washing machine leasing – this business model provides a benefit to both washing machine sellers and customers, as in this model longer-lasting machines are leased to customers who then have the option of upgrading to a different lease model if a more efficient model emerges[15];
5. Household tasks leasing – this business model involves the provision of household cleaning and home improvement products (e.g. for gardening, DIY) as services[16]; and

[12] Façade World (2016), *Façade Leasing – A circular business strategy for integrated facades*, Available at: http://www.climate-kic.org/projects/facade-leasing/ (Accessed 16 March 2017).
[13] European Parliament (2012), *Leasing Society, Case Study 2: General Motors—from selling waste disposal to resource management;* Available at: http://www.europarl.europa.eu/RegData/etudes/etudes/join/2012/492460/IPOL-ENVI_ET(2012)492460_EN.pdf (Accessed 17 March 2017).
[14] Lozano *et al* (2014), *Critical reflections on the Chemical Leasing concept*, Resources, Conservation and Recycling: 86, 53-60 (Accessed 31 March 2017).
[15] The Ellen MacArthur Foundation (2012), *But does it actually work?;* Available at: https://www.ellenmacarthurfoundation.org/news/but-does-it-actually-work (Accessed 17 March 2017).
[16] Gottberg, A. (2012), *Product Service Systems for Household Waste Prevention*, PhD thesis, Cranfield University; Available at: https://dspace.lib.cranfield.ac.uk/bitstream/1826/8630/1/Annika_Gottberg_Thesis_2012.pdf (Accessed 17 March 2017).

6. Clothes renting – this business model involves an online platform that enables the renting of high-profile, designer clothes at low prices. These websites are more prominent in the USA, but the UK has such sites too, such as MUD Jeans[17] and Hire the Catwalk[18] (see **Figure 7**).

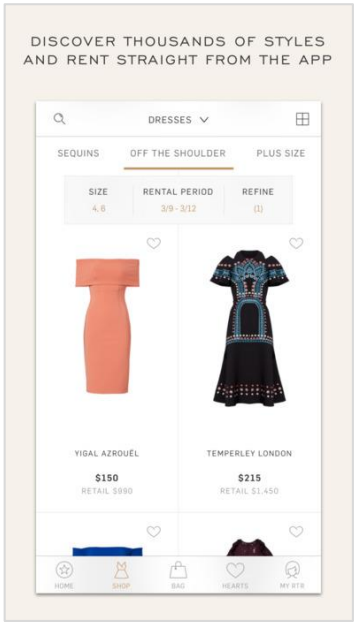

Figure 7: A clothes renting mobile application interface (Source: iTunes[19])

Apart from leasing models, pay-by-use and subscription-based services have also become more popular in recent years. One benefit that these business models bring to manufacturers, is that they can turn the machinery from capital expenditure (Capex) to operational expenditure (Opex). Rolls-Royce pioneered this approach in its jet-engine business, and other manufacturers have since followed.

Some popular subscription-based models include Kindle and Spotify, which have allowed the virtualisation of physical assets, such as books and music CDs, respectively. However, despite their popularity, many companies that have followed this business model, including Spotify, have not succeeded in becoming, or remaining, profitable, even after being in business for several years[20]. This is largely the result of an attempt to keep up with the public's new needs (e.g. digital, easy-to-access music) in a system that favours old regulations and legal requirements (e.g. music record labels holding ownership rights).

[17] MUD Jeans (2017), Lease A Jeans, Available at: http://www.mudjeans.eu/about-mud-jeans/ (Accessed 16 March 2017).
[18] Hire the Catwalk (2017), *About us;* Available at: http://hirethecatwalk.com/about-us (Accessed 4 April 2017).
[19] iTunes (2016), *Rent the Runway*, Available at: https://itunes.apple.com/us/app/rent-the-runway/id672853806?mt=8 (Accessed 4 April 2017).
[20] Spross, J. (2016), *The Catch-22 in Spotify's business model*, Available at: http://theweek.com/articles/626139/catch22-spotifys-business-model (Accessed 16 May 2017).

The effects of such virtualisation of assets CE initiatives are not explored further in terms of waste reduction, as their effects are less evidence based, and their effects are more likely to be realised over larger timescales.

Targeted LWARB focus areas (and estimated level of impact on them)

- Built environment (medium);
- Electricals (high);
- Textiles (medium-high); and
- Plastics (medium-low).

3.2.5 Smart predictive maintenance

Leasing business models can be taken one step further by including maintenance, upgrades and sometimes operation of the asset. Services may be monitored, repaired and upgraded remotely using embedded sensors and smart monitoring devices that anticipate problems and carry out maintenance works, thus expanding the life of assets (see **Figure 8**).

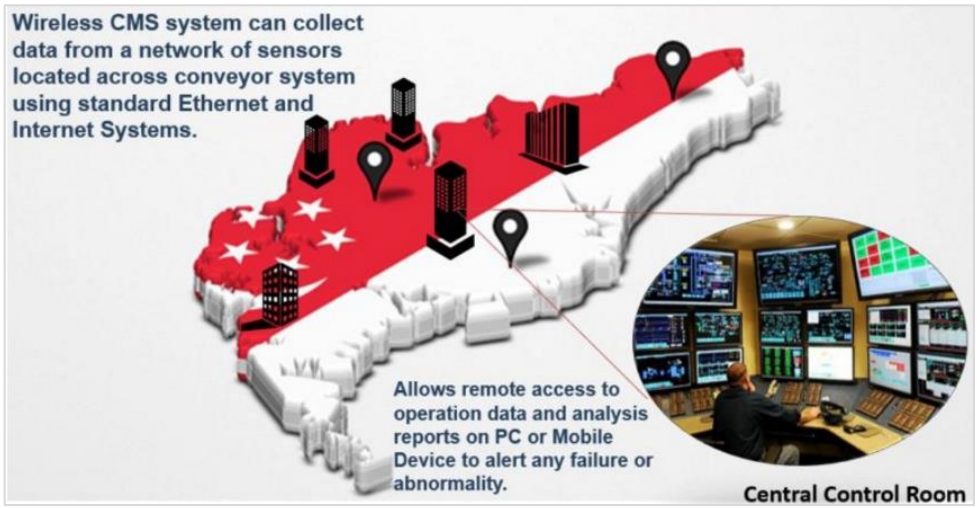

Figure 8: Example of remote, smart predictive maintenance in Singapore (Source: ETS Solutions[21])

With access to accurate real-time data, enabled by significant price decreases for sensor technology through IoT devices within an open-source digital ecosystem, companies can monitor assets, such as buildings, continuously. This enables predictive maintenance and enhanced asset performance and thereby, it can reduce Opex significantly[22], and prolong the service life of an asset.

[21] ETS Solutions (2017), *Predictive Maintenance Strategy for Building Operations: A Smart Approach*, Available at: http://etssolution-asia.com/predictive-maintenance-strategy-for-building-operations-a-smart-approach/ (Accessed 4 April 2017).
[22] European Parliament (2015), *The Internet of Things - Opportunities and challenges;* Available at:http://www.europarl.europa.eu/RegData/etudes/BRIE/2015/557012/EPRS_BRI(2015)557012_EN.pdf (Accessed 20 March 2017).

If a manufacturer produces new products to replace old ones too often, consumer resistance may set in. This has occurred at times in the computer industry when consumers have been unconvinced that a new wave of replacement products is giving sufficient extra value for switching to be worth their while.

As discussed further in **Section 3.2.6**, within the context of manufacturing systems there exist seven types of waste, arising from different components of the system[23]. One of these includes inventory issues arising from inventories that are not directly required to fulfil current customer orders. Inventory includes raw materials, work-in-progress and finished goods. Additional inventory requires additional handling and space. Its presence can also significantly increase extra processing. As a result, combining inventory management with data analytics can improve the way in which manufacturing process can become more resource efficient[24]. Predictive intelligence alerts you to conditions that lead to waste, while superior control addresses variability so that specifications can be met even at higher production rates[25].

Smart predictive maintenance can be implemented in order to improve materials and processes directly affecting the built environment. However, any big data analytics that can be applied to improve construction practices and therefore cut down CDEW, are explored as part of the urban analytics CE initiative.

Targeted LWARB focus areas (and estimated level of impact on them)

- Built Environment (medium-high);
- Electricals (high); and
- Plastics (high).

3.2.6 Urban analytics

The Internet of Things (IoT) is growing rapidly, with an estimated 25 billion connected objects throughout the world by 2020, and an added value from the IoT of US$1.9 trillion by the same year. The IoT can thus be a key contributor to achieving the European Union's (EU's) Europe 2020 strategy for smart, sustainable and inclusive growth[26].

The use of real-time data processing and predictive analytics can enable improved resource planning (see **Figure 9**). New technology innovations which employ predictive analysis allow city planners and public service providers to create safer, more responsive and efficient urban environments. Utility services, such as waste, can be improved through the targeted application of analytics and visualisations.

[23] Ohno, T. (1978), *Toyota Production System: Beyond Large-Scale Production*; Available at: http://www.ce.berkeley.edu/~tommelein/lci/tps_ono.pdf (Accessed
[24] Choen, M. (2015), *Inventory Management in the Age of Big Data*, Available at: https://hbr.org/2015/06/inventory-management-in-the-age-of-big-data (Accessed 20 March 2017).
[25] Plantweb (2003), *Reducing operations & maintenance costs;* Available at: http://www2.emersonprocess.com/siteadmincenter/PM%20Central%20Web%20Documents/plantweb-ops-maint.pdf (Accessed 17 March 2017).
[26] European Parliament (2015), *The Internet of Things Opportunities and challenges;* Available at: http://www.europarl.europa.eu/RegData/etudes/BRIE/2015/557012/EPRS_BRI(2015)557012_EN.pdf (Accessed 20 March 2017).

This includes improvements to maintenance schedules, asset management and incident management.

Figure 9: Example of waste generation data analytics (source: Warwick Institute for the Science of Cities[27])

There is an enormous opportunity in utilising this data to enable more intelligent, efficient and predictive services – however current estimates suggest that only 0.5% of available data are being used. Significant amounts of real-time data can be generated from an increasing number of sources and technologies, ranging from sensor technology to crowd-sourced data.

In the construction and manufacturing industry, lean thinking can be applied in conjunction with big data analytics in order to optimise processes, improve productivity and reduce wastage and waste generation. The key to applying advanced analytics in lean-production environments is to view data through the lens of continuous improvement and not as an isolated series of one-offs[28].

It has been shown that lean construction processes can achieve a reduction in construction costs, and one important way in which this is achieved is through the targeting of all seven forms in which waste can arise in construction, including[29,30]:

- Transport (i.e. unnecessary motion);
- Inventory (i.e. waste of stock on hand);
- Motion (i.e. extra steps taken by employees and equipment to accommodate inefficient layout, defects etc.);
- Waiting (i.e. periods of inactivity);

[27] Warwick Institute for the Science of Cities (2015), *Urban Waste Analytics;* Available at: http://www.wisc.warwick.ac.uk/files/6414/6222/1818/Nick.pdf (Accessed 4 April 2017).
[28] McKinsey & Company (2014), *When big data goes lean;* Available at: http://www.mckinsey.com/business-functions/operations/our-insights/when-big-data-goes-lean (Accessed 20 March 2017).
[29] Ohno, T. (1978), *Toyota Production System: Beyond Large-Scale Production;* Available at: http://www.ce.berkeley.edu/~tommelein/lci/tps_ono.pdf (Accessed 30 March 2017).
[30] CIRIA (2011), *Transforming construction using lean thinking*, Event report E11102, (Accessed 20 March 2017).

- Over-production;
- Over-processing;
- Defects (i.e. making defective products); and
- Skills (i.e. lack of up-to-date skills).

Building information modelling (BIM) can be used in building design within the larger context of lean thinking and big data analytics. BIM tracks building material and component attributes to facilitate future maintenance, as well as reuse and recycling. It has already been shown that the use of BIM in conjunction with improved project data analytics, has achieved a 95% completion of projects to budget, 20% reduction in cost/m^2, and 70% on time project completion rate[31].

Digital waste stream management systems offer the opportunity to improve the re-use of generated waste, thus strengthening demand and supply networks. Such systems aid in mapping existing supply chains according to demand. Similarly, on a local or city scale, a digital marketplace for waste collection can be provided that offers pick-ups on demand instead of using predetermined schedules.

In cities, householders may use a chip card to dispose of their waste. This enables local authorities to measure the quantity of waste disposed, but also identify the location and time of disposal. This can help waste collectors to estimate the ideal times at which to empty containers. It also allows a better understanding and monitoring of waste arisings, and this can help in the provision of a more tailored and targeted public engagement and other types of waste reduction campaigns. This strategy has been applied in Songdo 'smart city' in South Korea[32], which has been operating with the use of smart infrastructure for the provision of many services, including facilities management and citizen information services.

Targeted LWARB focus areas (and estimated level of impact on them)

- Built environment (medium-high);
- Food (low-medium);
- Textiles (medium-high);
- Electricals (medium-high); and
- Plastics (medium-high).

3.2.7 Exchange platforms

The part of the sharing economy which involves the sharing of assets, skills and services for a fee (including membership fees), or in exchange of another material or service, is explored under the Exchange platforms CE initiative. In other words, the giveaway of materials and/or services occurs on the condition of receiving something in return.

[31] CIRIA (2013), *Implementing Lean in construction;* Available at: https://ciria.sharefile.com/share?#/view/45eb269745974040 (Accessed 4 April 2017).
[32] *Songdo IBD – About;* Available at: http://songdoibd.com/about/ (Accessed 16 March 2017).

Exchange platforms can be used to target CDEW. Construction companies can sell their surplus materials through surplus construction materials selling services (see **Figure 10**), some of which include:

1. LOOP[33] – an online trading platform for contractors, designers, investors and manufacturers to buy and sell excess building materials. Developed by London-based start-up Circology, the digital marketplace aims to help reduce CDEW through the extended use of construction materials in a commercially viable way by linking supply and demand.
2. Recipro[34] – an online network that was established in the UK in 2008, in order to help divert surplus construction materials into projects that require them.
3. Enviromate[35] – an online trading platform connecting anyone who has surplus construction waste (including householders). It works both as a community-based platform, as well as a means for connecting businesses nationwide. A core focus at Enviromate is the diversion and donation of surplus construction materials generated by larger construction developments, to local community and charitable projects across the UK.
4. Globechain[36] - a London-based online trading platform connecting businesses, charities and people to enable them to exchange unused/surplus construction materials. Unlike the trading platforms above, Globechain also offers the opportunity to exchange office equipment (e.g. carpets, flooring, furniture), as well as retail equipment (e.g. frames, window displays, shopping baskets, display tables) and home equipment (e.g. home accessories, household appliances). Members taking items can take as many items as they want for free. However, to list and upload items, members pay a listing fee which can either be a Pay as you go fee per upload or they can be set up as an annual member and have unlimited use of the platform.

[33] Lo, C. – Designbuild-network (2016), *Waste not, want not: new start-up aims to clean up surplus construction material;* Available at: http://www.designbuild-network.com/features/featurewaste-not-want-not-new-start-up-aims-to-clean-up-surplus-construction-material-4996182/ (Accessed 4 April 2017).
[34] Recipro (2016), *About us;* Available at: http://www.recipro-uk.com/about-us (Accessed 23 March 2017).
[35] Enviromate (2017), *How it works;* Available at: https://www.enviromate.co.uk/how-it-works (Accessed 23 March 2017).
[36] Globechain (2017), *How it works*, Available at: https://www.globechain.com/ (Accessed 11 April 2017).

Figure 10: A Crossrail site where LOOP is being implemented (Source: Designbuild-network[37])

Householders can also benefit from exchange platforms, as they can sell off (using actual, or made-up currency (e.g. tokens), exchange or rent out their clothes, their DIY tools, other household items and food.

Some successful exchange platforms used by businesses and householders in the UK include:

1. Too Good To Go[38] – A mobile application that is available throughout the UK, including London, since January 2016. It connects potential customers to restaurants and cafes which want to give away their surplus food. Users can locate available restaurants in their area and then, they can go within a given timeframe and collect surplus food for a highly reduced price (e.g. 80% of original price);
2. Yerdle[39] – Registered users of the service can sell and buy used, unwanted items in exchange for proprietary Credits, paying only shipping to send and receive objects. The site's explicit mission is to reduce the number of new consumer purchases by 25%. Corporate partnerships may help reach this goal; a co-branding exercise with outdoor gear manufacturer Patagonia in 2014 invited users to Yerdle-facilitated 'swap meets' where they could exchange used Patagonia goods in person, reducing waste and enhancing both brands' public image; and

[37] Designbuild network (2016), *Waste not, want not: new start-up aims to clean up surplus construction material*, Available at: http://www.designbuild-network.com/features/featurewaste-not-want-not-new-start-up-aims-to-clean-up-surplus-construction-material-4996182/ (Accessed 4 April 2017).
[38] Too Good To Go (2017), *About;* Available at: http://toogoodtogo.co.uk/, (Accessed 23 March 2017).
[39] Yerdle (2016), *Yerdle helps leading brands develop re-use programs;* Available at: https://www.yerdle.com/ (Accessed 15 March 2017).

3. Edinburgh Tools Library[40] – It started in 2013 and it is the UK's first tool library, lending their members tools for DIY, gardening, decorating and machine repair, so that they do not need to buy their own;
4. Library of Things[41] - Having started in 2014 in West Norwood, it is London's first community-created tools library. It is located within the local public library, and since its inception it has been crowd funded almost £15,000. A maximum of five items can be borrowed for up to one week, for a maximum fee of £15. Apart from allowing users to borrow DIY, gardening tools, kitchenware, camping kits and events equipment, the tools library offers one-to-one learning sessions and workshops. In this way, it promotes a community culture and facilitates the sharing of skills and expertise.

Numerous clothes exchange online and mobile applications are in operation around the world, but with particular presence and popularity in the USA. Such applications allow users to buy and sell their unwanted clothes (with a specific preference for high-profile brands) for up to 70% of the retail price (e.g. Poshmark[42]).

Targeted LWARB focus areas (and estimated level of impact on them)

- Built Environment (medium);
- Food (medium-high);
- Textiles (high);
- Electricals (medium-high); and
- Plastics (medium-high).

3.2.8 Sharing platforms

Sharing economy is defined as 'an economic system based on sharing underused assets or services, for free or for a fee, directly from individuals'[43].

Collaborative consumption is defined as 'the reinvention of traditional market behaviours—renting, lending, swapping, sharing, bartering, gifting—through technology, taking place in ways and on a scale not possible before the internet'[44].

For the purposes of this study, collaborative consumption is explored under the Sharing platforms CE initiative, and it includes means by which people can share their goods and services for free and without necessarily expecting anything in return from the same person (see **Figure 11**).

[40] Edinburgh Tool Library (*no date*), *Story;* Available at: http://edinburghtoollibrary.org.uk/ (Accessed 24 March 2017).
[41] Library of Things (2017), *How it works*, Available at: http://www.libraryofthings.co.uk/how-it-works/ (Accessed 16 May 2017).
[42] Poshmark (2017), *Buy & Sell;* Available at: https://poshmark.com/ (Accessed 24 March 2017).
[43] Botsman, R. (2015), *Defining the Sharing Economy: What is Collaborative Consumption –and what isn't*, Available at: https://www.fastcompany.com/3046119/defining-the-sharing-economy-what-is-collaborative-consumption-and-what-isnt?show_rev_content (Accessed 11 April 2017).
[44] Ibid.

Collaborative consumption can thrive under initiatives and technologies that promote the sharing of equipment, products, consumer goods, as well as skills and expertise.

Some types of sharing platforms include:

- Shared tools platform – Neighbourhood sharing platforms allowing people to lend and borrow underutilised household items (e.g. power tools);
- Shared skills platform – Skills sharing platform allow people to get free help from neighbours with domestic tasks, such as bicycle repairs or gardening, often in exchange for other tasks. This can minimise the probability that people will discard their items, simply because they are unable to repair them; and
- Shared industrial resources platform – An industrial sharing economy platform, which essentially matches unwanted resources by one business with resource requirements of another business.

Figure 11: A food sharing platform interface (Source: The Lead[45])

Numerous online sharing applications are available for use throughout the UK, and they can also be used in London. Some of these include:

1. Streetbank[46] – An online application that allows users to give away unwanted household goods, share their home equipment and appliances and sharing skills (e.g. DIY) with their neighbours; and

[45] The Lead (2014), *Food sharing goes global*, Available at: http://www.theleadsouthaustralia.com.au/industries/technology/food-sharing-goes-global/ (Accessed 4 April 2017).
[46] Streetbank (2017), *About us*, Available at: https://www.streetbank.com/about?locale=en-GB (Accessed 21 March 2017).

2. OLIO[47] – A free mobile application that enables food sharing between its users. Users can include householders, but also local businesses. This enables users to give away their surplus food and thus, avoid food waste. The application which became active in January 2016 by only being available to North London users, has since expanded to 41 countries. Due to its popularity, OLIO now allows its users to share other items, including small household appliances, toiletries, books and toys.

To make the sharing economy sustainable, public authorities must first build an economic and regulatory framework that is favourable to 'virtuous' models[48].

Targeted LWARB focus areas (and estimated level of impact on them)

- Food (medium-high);
- Textiles (medium-high);
- Electricals (medium-high); and
- Plastics (medium-high).

3.2.9 Urban farming

Urban farming can take many forms, including vertical farming practices taking place in industrial warehouses in large urban areas, such as London[49]. However, the urban farming practices that are looked at as waste reduction CE initiative, include:

1. Rooftop farming – An urban farming method that sees the growth of fruit and vegetables on rooftops using classic raised beds (see **Figure 12**) or more advanced systems like hydroponics, aeroponics and aquaponics. This helps to meet local fruit and vegetable demands with local produce;
2. Urban community gardens – Putting land into community use to grow affordable, fresh, organic food, and support others to do so. Areas for food production (urban gardens) as well as for food processing and preservation are established in common. People invest time and energy and take over system activities (e.g. food or bio-waste transports, meal preparation for delivery on demand, etc.);
3. Commercial food distribution – The distribution of local grown product from rooftop and other similar urban farming activities to local businesses (e.g. cafes, restaurants, food manufacturers etc.).

[47] OLIO (2016), *Our impact;* Available at: https://olioex.com/about/our-story/ (Accessed 21 March 2017).
[48] Demailly D. (2014), *The sharing economy: make it sustainable;* Available at: http://www.iddri.org/Evenements/Interventions/ST0314_DD%20ASN_sharing%20economy.pdf (Accessed 16 February 2017).
[49] Grow Up Urban Farms (2014), *Unit 84,* Available at: http://growup.org.uk/growup-urban-farms/ (Accessed 23 April 2017).

Figure 12: Rooftop farming in London (Source: Micha Thainer, The Independent[50])

Urban farming can offer a number of social benefits, such as alleviating poverty, creating a community spirit, bringing people closer to the environment and helping them value more their food, as they are directly involved in its production and distribution.

Although urban farming can tackle food waste more through reuse and recycling, as it turns large amounts of food waste into compost, citizen groups can take steps to educate the public and build awareness to reduce waste.

Urban farming is a good opportunity to tackle packaging waste. The locally produced fruit and vegetable requires less or no packaging at all, as they are intended for local, immediate consumption[51].

Despite their relatively small size, urban farms grow a surprising amount of food, with yields that often surpass those of rural farms. This is possible because:

1. Urban farms may not be as prone to pests (e.g. insects), and they do not have to deal with intrusive animals (e.g. rabbits);
2. Urban farmers can walk around their plots in minutes, addressing problems as they arise and harvesting produce at its peak; and

[50] Thainer, M. (2012), *Next stop, the Olympics: Urban farmers are digging for eco-victory*, Available at: http://www.independent.co.uk/environment/green-living/next-stop-the-olympics-urban-farmers-are-digging-for-eco-victory-6286753.html#gallery (Accessed 4 April 2017).
[51] Community Supported Agriculture (*no date*), (*no title*); Available at: https://communitysupportedagriculture.org.uk/what-is-csa/ (Accessed 23 March 2017).

3. Urban farmers can plant more densely because they hand cultivate, nourish their soil more frequently and micromanage applications of water and fertiliser.

Targeted LWARB focus areas (and estimated level of impact on them)

- Food (low-medium); and
- Plastics (high).

3.2.10 Laser-etched branding

Supermarkets, food and grocery stores can reduce, or even fully eliminate, the amount of plastic and paper used for packaging fruits and vegetables. This can be achieved through laser-etched branding.

The approach uses a high-definition carbon dioxide laser to etch the desired brand onto each piece of fruit or vegetable, removing pigment from the outer layer of cells and leaving a permanent mark (see **Figure 13**). The process does not affect the integrity, taste or shelf-life of the produce, and the etched area is safe to be eaten. By removing the need for stickers and packaging within food distribution, the approach helps to cut down the use of plastics, paper, ink and adhesives. It is also easier to track the origin of produce as the marks cannot be removed.

This technology has already been adopted by the international food distributor, Eosta[52], as well as the Dutch fruit and vegetable provider Nature & More in collaboration with the Swedish supermarket ICA[53]. In the UK, the method has been adopted by Marks & Spencer's food stores, which sell laser-etched coconuts[54].

[52] Eosta (2013), *Natural Branding FAQ;* Available at: http://www.eosta.com/en/content/natural-branding-faq (Accessed 15 March 2017).
[53] Pullman, N. (2017), Swedish supermarkets replace sticky labels with laser marking; Available at: https://www.theguardian.com/sustainable-business/2017/jan/16/ms-and-swedish-supermarkets-ditch-sticky-labels-for-natural-branding (Accessed 16 March 2017).
[54] Ibid.

Figure 13: Laser-etched fruit and vegetable

Targeted LWARB focus areas (and estimated level of impact on them)

- Plastics (high).

3.3 Waste reduction data collection and findings

3.3.1 Overview

The waste reduction potential of each of the nine CE initiatives on each of the three waste types (i.e. CDEW, C&IW and HW) are given in **Table 1.**

All the waste reduction percentages that were applied to the updated GLA model are given in **Table 2**. The given percentages were all based on evidence based assumptions and calculations, all of which can be found in **Appendix A**.

Some CE initiatives have the same target (e.g. elimination of avoidable food waste). For these initiatives the maximum waste reduction percentage was assumed, which suggests that these CE initiatives are equally effective. In some of these cases, a qualitative assessment was also carried out in order to determine which one is actually more effective (i.e. is expected to have a faster, larger uptake by businesses and the general public) (see **Appendix A**).

The sources used to support the waste reductions in **Table 2**, are also given in **Appendix A**. For a number of CE initiatives, examples of companies or projects that have adopted such CE initiatives are also given. These are not necessarily in London or even in the UK, as local examples are, in many cases, unavailable. As a result, the given case studies should be treated as examples of how to apply (or in some cases avoid) CE business models in order to achieve waste reduction, together with a number of other resource management, financial, environmental and social benefits (see **Appendix A**).

Table 1: The waste reduction impacts of each CE initiative

	Waste streams		
CE initiative	**CDEW**	**C&IW**	**HW**
Additive manufacturing	✓✓✓	n/a	n/a
Modularity	✓✓	n/a	n/a
Leased assets	✓✓	✓✓	✓✓
Smart predictive maintenance	n/a	✓✓	n/a
Urban analytics	✓✓✓	✓✓	✓✓
Exchange platforms	✓✓	✓✓✓	✓✓✓
Sharing platforms	n/a	✓✓	✓✓✓
Urban farming	n/a	n/a	✓✓✓
Laser-etched branding	n/a	✓✓✓	n/a

Key	**Description**
n/a	Reduction of specific waste stream not targeted by initiative
✓✓	Moderate effect of CE initiative on waste reduction
✓✓✓	High effect of CE initiative on waste reduction

Table 2: Summary of waste reductions

CE initiative	Type of waste	Sector and/or process	Percentage (%) reduction
Additive manufacturing	CDEW	Construction-scale additive manufacturing	45
Modularity	CDEW	Overall prefabrication effects on whole lifecycle	6.5
Leased assets	CDEW	Façade leasing	16
Leased assets	C&IW	Selling resource management instead of waste disposal in manufacturing	25
Leased assets	C&IW	Chemical leasing for cleaning operations	92
Leased assets	C&IW	Battery leasing	25
Leased assets	HW	Clothes renting	30
Leased assets	HW	Washing machine leasing	14
Smart predictive maintenance	C&IW	Improved inventory management	18
Urban analytics	CDEW	Lean thinking	32
Urban analytics	CDEW	BIM	45
Urban analytics	C&IW	Waste tracking and analytics applied by restaurants and food service providers	24
Urban analytics	C&IW	Waste tracking and analytics applied by/on behalf of retailers	35

CE initiative	Type of waste	Sector and/or process	Percentage (%) reduction
Urban analytics	HW	Mobile applications for meal planning/making most of food available at home	69
Exchange platforms	CDEW	Surplus construction materials selling services	14
Exchange platforms	C&IW	Resource exchange services for businesses (office equipment)	5
Exchange platforms	C&IW	Resource exchange services for businesses (food)	10
Exchange platforms	HW	Clothes trading applications	5
Exchange platforms	HW	Tools library	12
Sharing platforms	C&IW	Surplus food sharing mobile applications used by supermarkets	10
Sharing platforms	HW	Unwanted home items sharing mobile application	40
Sharing platforms	HW	Surplus food sharing mobile applications	69
Urban farming	HW	Urban agriculture projects	21
Laser etched branding	C&IW	Laser-etched bar coding in supermarkets (plastic)	34
Laser etched branding	C&IW	Laser-etched bar coding in supermarkets (paper)	69

3.4 Time-uptake relationship

3.4.1 Overview

The time-uptake relationship is assessed separately for each CE initiative. The uptake is based on the technology adoption lifecycle[55] (see **Figure 14**). More specifically, when the 'Early Majority' (i.e. a minimum of 34% of the population) have started actively participating in the CE initiative, this is the time when the CE initiative is considered to have taken off.

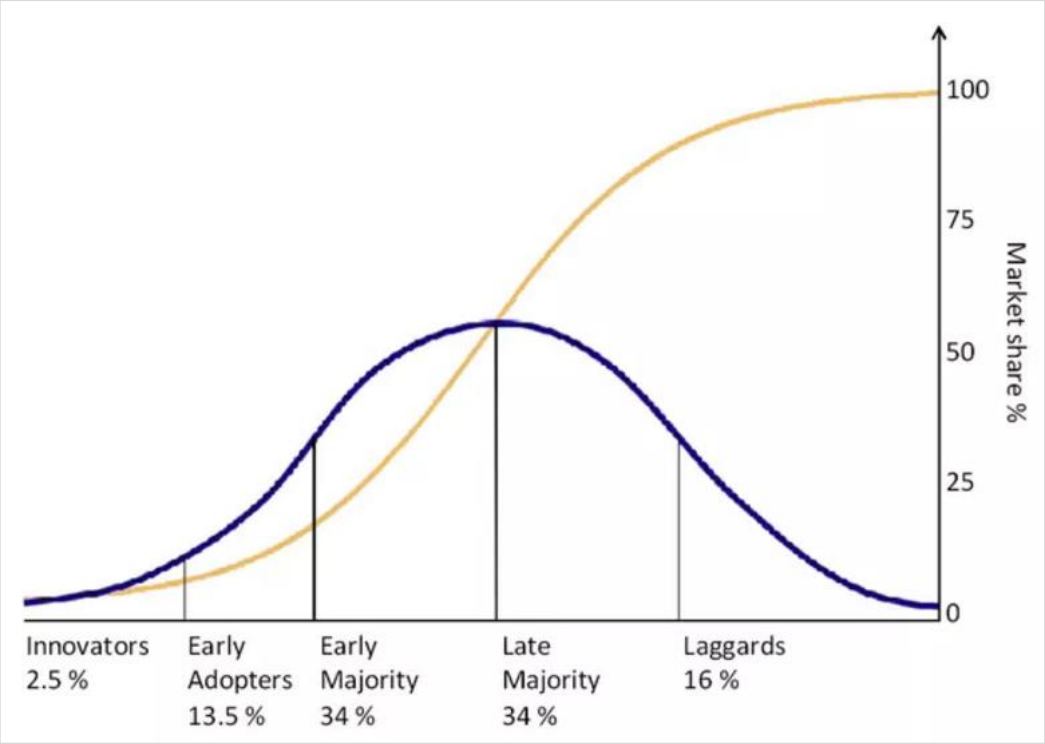

Figure 14: Technology adoption lifecycle

However, as it is difficult to assess this quantitatively, a qualitative assessment was undertaken for each waste type (i.e. CDEW, C&IW and HW) for each CE initiative. Based on this assessment, each of the nine CE initiatives was given a rank from 1-9 (with one being the first to be taken up).

It should be noted that the ranks allocated to each CE initiative, are assumed to be fixed, regardless of whether an emphasis will be given on a specific waste type within each CE initiative.

[55] On Digital Marketing (2017), *The 5 Customer Segments of Technology Adoption;* Available at: https://ondigitalmarketing.com/learn/odm/foundations/5-customer-segments-technology-adoption/ (Accessed 27 March 2017).

The assessment was based on:

1. Current levels of uptake;
2. Projected future levels of uptake;
3. Main barriers to uptake; and
4. Level of public engagement required to facilitate uptake.

3.4.2 Chosen time factor

The detailed qualitative assessment carried out for each CE initiative can be found in **Appendix B**.

Behavioural change initiatives have shown that the uptake will, in general, be slower to achieve with householders than the commercial sector (including construction).

Based on uptake ranking, we have determined the period of time that might be required for the full effect of the initiative to be achieved. **Table 3** sets out the period of time assigned to each initiative and waste type, along with the year when the full effect is expected. Full achievement is represented by the value '1' in the time 't' variable, further described in **Section 5.1**.

Table 3: The predicted uptake for each CE initiative

CE initiative	CDEW	C&IW	HW
Additive manufacturing	15 years (2031)	n/a	n/a
Modularity	5 years (2021)	n/a	n/a
Leased assets	15 years (2031)	10 years (2026)	15 years (2031)
Smart predictive maintenance	n/a	10 years (2026)	n/a
Urban analytics	10 years (2026)	10 years (2026)	15 years (2031)
Exchange platforms	10 years (2026)	20 years (2036)	25 years (2041)
Sharing platforms	n/a	20 years (2036)	25 years (2041)

CE initiative	CDEW	C&IW	HW
Urban farming	n/a	n/a	15 years (2031)
Laser-etched branding	n/a	10 years (2026)	n/a

3.4.3 Comparison with other countries

3.4.3.1 Overview

To understand the feasibility of realising significant waste reduction and a general move towards resource efficiency at a faster rate within the timeframe of the London Plan, a comparison was made to two countries that have demonstrated a successful move towards resource efficiency, improved waste management and CE. The two chosen countries are Slovenia and Japan.

Slovenia was chosen because it is an exemplary case of a country which, only 15 years ago, had almost zero reuse, recycling and recovery rates of municipal waste, but has since made a rapid move towards applying both the waste hierarchy and CE. A particular focus is given to the capital, Ljubljana, which is part of the Ellen MacArthur Foundation's Circular Cities Network[56], and in 2014, it became the first European capital to declare a zero waste goal[57]. The small town of Vrhnika has also been observed, as it is one of Europe's most exceptional waste management success stories.

Japan was chosen because it is a country that has focused on resource efficiency and CE principles since the beginning of the 21st century, by passing the Law for the Promotion of Efficient Utilisation of Resources in 2000. The Law aimed at developing a framework for the promotion of waste reduction, reuse and recycling[58]. A focus is given to the cities of Yokohama, a large city, and Kamakura, a medium-sized city.

Please note that CDEW waste reduction targets were not assessed for Slovenia and Japan. In addition, any data comparisons have assumed that the data reporting provided by each country is complete.

[56] Ellen MacArthur Foundation (2016), *The Ellen MacArthur Foundation launches Circular Cities Network*, Available at: https://www.ellenmacarthurfoundation.org/news/circular-cities-network (Accessed 24 May 2017).
[57] Zero Waste Europe (2015), *The Story of Ljubljana - First European Capital to Move towards Zero Waste*, Available at: http://www.zerowasteeurope.eu/zw-library/case-studies/ (Accessed 24 May 2017).
[58] Global Environment Centre Foundation (2011), *Law for Promotion of Effective Utilization of Resources*, Available at: http://nett21.gec.jp/Ecotowns/data/et_c-05.html (Accessed 31 May 2017).

Domestic Material Consumption (DMC) [59] is an important indicator of the level at which economic growth is coupled to the use of natural resources. **Figure 15**, indicates that although Slovenia has had a significantly higher DMC compared to Japan and the UK, its DMC has decreased rapidly over the past decade.

A comparison of municipal waste generation per capita between 1995 and 2014 is given for Slovenia, Japan and the UK in **Figure 16**. It is evident that waste generation per capita remains higher in the UK, compared to both Slovenia and Japan. Comparing the results of **Figure 15** and **Figure 16**, it is evident that despite its relatively low DMC, the UK has a higher per capita municipal waste generation rate than either Slovenia or Japan.

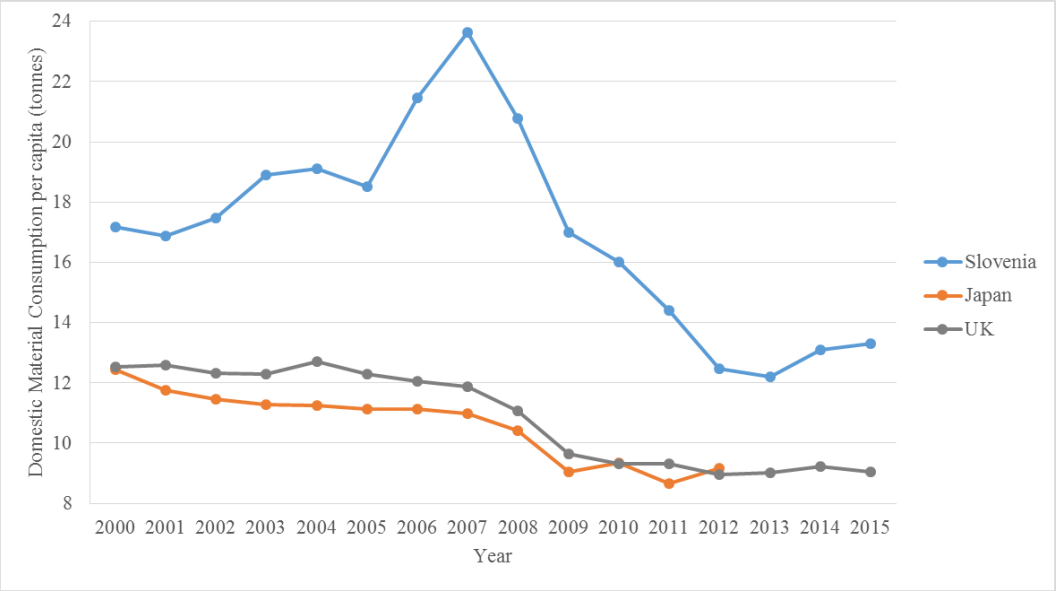

Figure 15: DMC per capita in Slovenia, Japan and the UK (Source: Knoema, 2014[60])

[59] DMC is defined as the total amount of materials directly used in the economy, minus the materials that are exported.
[60] Knoema (2014), *Municipal waste, Generation and Treatment*, Available at: https://knoema.com/MUNW/municipal-waste-generation-and-treatment?location=1000170-japan&action=export (Accessed 01 June 2017).

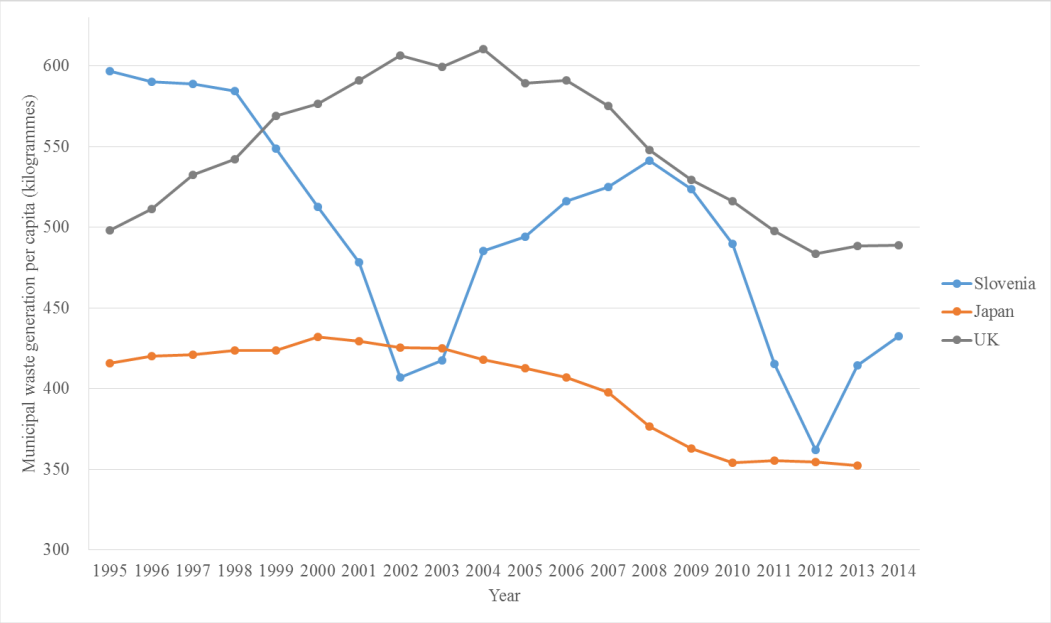

Figure 16: Municipal waste generation per capita in Slovenia, Japan and the UK (Source: Knoema, 2014[61])

A comparison of the proportion of material recovery, including both recycling and composting, between 1995 and 2014 is given for Slovenia, Japan and the UK in **Figure 17**.

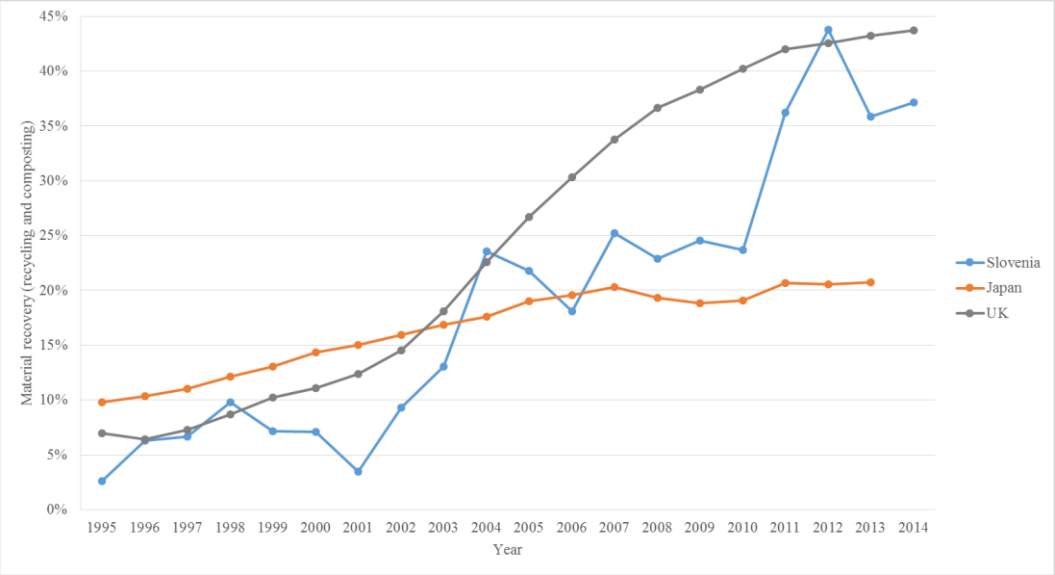

Figure 17: Material recovery (recycling and composting) in Slovenia, Japan and the UK (Source: Knoema, 2014[62])

It is evident from **Figure 17** that Slovenia has demonstrated the fastest move towards recycling and composting over the last 20 years. At the same time, the UK appears to be a better overall recycler since the beginning of the 21st century. This result, together with the higher waste generation per capita, demonstrates the

[61] Ibid.
[62] Ibid.

higher need for the UK to move up the waste hierarchy and focus more on waste reduction.

Figure 18 shows that Slovenia has been sending negligible quantities of waste for incineration. This has contributed to the proactive nature of strategies implemented in the country for achieving better waste reduction and higher landfill diversion.

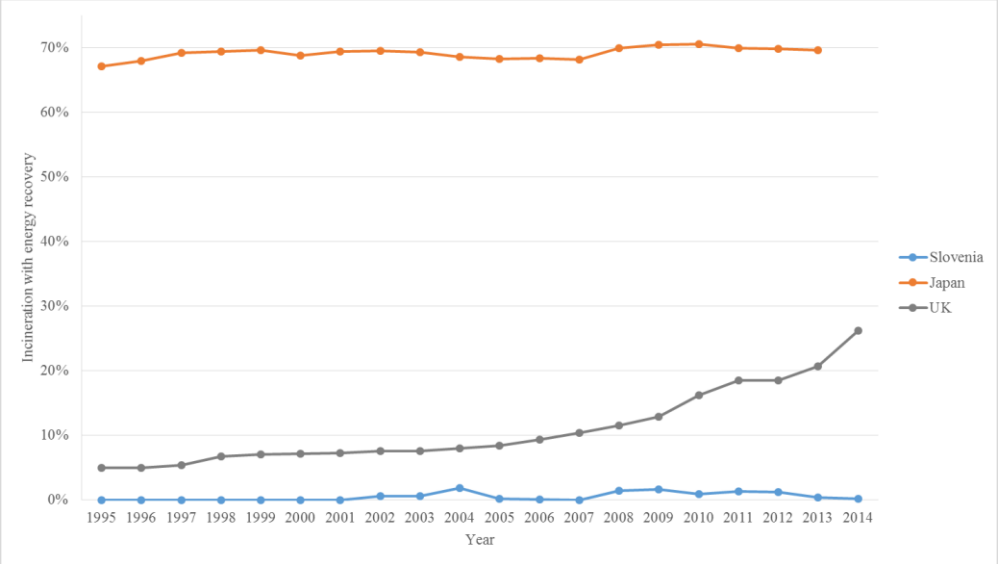

Figure 18: Incineration with energy recovery in Slovenia, Japan and the UK (Source: Knoema, 2014[63])

3.4.3.2 Slovenia

Implemented strategies

The country has ruled out building any incinerator in order to have the flexibility to continue reducing the currently non-recyclable waste fraction and push for waste reduction and recycling.

According to Snaga, the public utility company responsible for waste collection in Ljubljana and six suburban municipalities, the key to their success includes political support, good management and commitment to the zero waste goal.

Some strategies implemented by Snaga to promote waste reduction and reuse are as follows[64]:

- In 10 years (between 2004 and 2014), source segregation increased from only two recyclable waste streams (glass and packaging), to five recyclable waste streams (glass, packaging, paper, organic waste and other fractions collected from Ecoparks);

[63] Ibid.
[64] Snaga (2017), *On our way to sustainable society*, Available at: http://ec.europa.eu/environment/international_issues/pdf/7_8_february_2017/Gregoric.pdf (Accessed 2 June 2017).

- Despite the strong opposition expressed by residents to the introduction of kerbside collection of recyclables in 2012, Snaga lowered the frequency of collection for residual waste while it kept the collection of recyclables the same and it reinforced its communications campaigns;
- Snaga convinced the media to get them on board to help in the promotion of source segregation at household level;
- Snaga targets food waste reduction, together with the help of the media, local NGOs, and food service providers;
- In 2013, Snaga decided to move their key efforts away from awareness-raising on source segregation of recyclables, and towards encouraging citizens to reduce the amount of waste they produce, promoting reduction, reuse and responsible consumption;
- Waste reduction interventions and campaigns included 'Get used to reusing', which later expanded to a national level in cooperation with the Chamber of Commerce; 'Raise Your Voice Against Food Waste'; and 'Responsible and Ethical Consumerism';
- Snaga opened a reuse centre in Ljubljana in 2013, and it consists of a 'Repair Café' and a shop which also includes a sewing room and a workshop;
- Snaga created the 'House of Reuse' in a 'Minicity', which is a purpose-built area that aims to engage children in responsible resource use, through 30 thematic corners;
- In the integrated waste management facility of RCERO, Snaga's 'Trash Design' team creatively reuses, upcycles and recycles items that form the interior of the facility; and
- Snaga is currently planning the development of an alternative shopping centre in Ljubljana, which will include the first Slovenian store without packaging.

Strategies implemented in Vrhnika, by the local public waste management company, *Komunalno Podjetje Vrhnika* (KPV) include:

- Since 2002, residents have the opportunity to take their waste to a household waste recycling centre, where the waste is weighed and residents are rewarded with points that result in a reduction of their monthly waste collection bill;
- Extended producer responsibility has been introduced for certain WEEE, such as batteries and accumulators, which also helped in the reduction of household waste;
- The local reuse centre, called DEPO, where items are repaired, upgraded or disassembled to be used in new products, which are then sold on site, has been a success, generating significant revenue in its first year of operation;
- Any public engagement and method of communication is adapted to specific demographic groups and their particular characteristics;
- Changing public perception of waste: painted trucks white with flower motifs, cleaned bins regularly and created an attractive entrance to the KPV collection centre, with a park featuring lawns and flowerbeds; and

- KPV offers educational lectures aimed at five different age groups, from nursery school age to university students.

Waste reduction and landfill diversion success

- Resource productivity[65] in Slovenia has been on a significant rise since 2007, as DMC, appears to be decoupling from the gross domestic product (GDP)[66];
- In 10 years (between 2004 and 2014), source segregation of recyclables increased from less than 5% to 59%;
- By 2014, the average resident in Ljubljana produced just 283kg of waste, 61% of which was recycled or composted (this is 41% lower than the EU average of 481kg of waste per capita);
- Almost 90% of people in Ljubljana give surplus, unwanted things away, sell them or take them to the reuse centre, which is located in the city;
- In just two years, the number of items sold per day at the reuse centre, increased from 50 to 140 per day;
- In 20 years, Vrhnika moved from almost 100% landfilling, to 76% recycling rates; and
- From 201kg/capita of residual waste in 2004, concerted action has managed to reduce this quantity to 80kg/capita in 2013 in Vrhnika[67], which is equal to a 60% reduction in less than 10 years;

Time factor based on Slovenia

Slovenia's example indicates that a faster reduction in HW could be achieved using exchange platforms and sharing platforms. Other CE initiatives that might also benefit from faster uptake at the household level if the same kind of strategies implemented by Slovenia were followed include 'leased assets and urban farming'.

Table 4 summarises the predicted uptake of each CE initiative if an approach closer to that of Slovenia is adopted. Please note that the time factors given in **Table 4**, have not been applied to the model in the **supplementary MS Excel document** and are only given as a guidance.

[65] Resource productivity is calculated as 'gross domestic product' (GDP)/Domestic Material Consumption (DMC).
[66] European Environment Agency (2015), *DMC, GDP, resource productivity*, Available at: https://www.eea.europa.eu/data-and-maps/daviz/dmc-gdp-resource-productivity-population-1#tab (Accessed 24 May 2017).
[67] Waste Management World (2014), *Trash Talk: 70% EU Recycling Target*, Available at: https://waste-management-world.com/a/trash-talk-70-eu-recycling-target (Accessed 2 June 2017).

Table 4: The predicted uptake for each CE initiative (Slovenia experience)

CE initiative	CDEW	C&IW	HW
Additive manufacturing	15 years (2031)	n/a	n/a
Modularity	5 years (2021)	n/a	n/a
Leased assets	15 years (2031)	10 years (2026)	10 years (2026)
Smart predictive maintenance	n/a	10 years (2026)	n/a
Urban analytics	10 years (2026)	10 years (2026)	15 years (2031)
Exchange platforms	10 years (2026)	15 years (2031)	10 years (2026)
Sharing platforms	n/a	15 years (2031)	10 years (2026)
Urban farming	n/a	n/a	10 years (2026)
Laser-etched branding	n/a	10 years (2026)	n/a

3.4.3.3 Japan

Implemented strategies

The high cost of incineration facilities and a strong push to close incinerators has become a strong incentive for waste reduction and recycling in many major Japanese cities.

Strategies implemented in Japan include:

- Under the Law for the Promotion of Efficient Utilisation of Resources, manufacturers are legally required to run disassembly plants, with material recovery being a legal requirement;
- In 2003, the Fundamental Plan for Establishing a Sound Material-Cycle Society was developed, which emphasised the need for reducing material consumption in upstream industries (e.g. manufacturing), since, it was

recognised that waste reduction can ultimately be achieved by reducing the amount of materials entering the supply chain;

- Japan's Food Recycling Law was enacted in 2001 and revised in 2007 in order to promote the reutilisation of food resources;
- The revision of the Food Recycling Law required periodical reporting of waste generation and recycling by all operators generating more than 100 tonnes of food waste;
- Food manufacturers and wholesalers have to deliver the product within the first third of the shelf-life and the product has to be sold before the end of the second third;
- Japan focused on taking up energy efficient technologies, as these improve resource productivity, which is done by a systematic approach, involving the effective and efficient promotion of cleaner production methods and integrated waste management; and
- Before the full implementation of the Food Recycling Law in 2014, target setting for different food production industries was reviewed following the submission of mandatory reporting of food waste generation.

Strategies implemented in the city of Yokohama include[68]:

- In 2003, Yokohama launched a campaign coined 'G30' (G stands for *gomi*: rubbish) targeting a 30% reduction in waste by 2010 compared to 2001;
- G30 increased source segregated recyclable waste streams from five to 10;
- G30 was extensively promoted by the local media, including all communications platforms; and
- Pilot studies were carried out initially, in selected areas of the city, where residents were supported in the use of the new waste and recycling collection services.

Strategies implemented in the city of Kamakura include[69]:

- The city started the 'Garbage Dieting' campaign in 1990, which aimed at redirecting waste from landfill, mainly through high quality source segregation of recyclables;
- Under 'Garbage Dieting', the city officials manned waste collection stations to address problems, answer questions and raise public awareness;
- Under the city's 3R Promotion Project Subsidy Programme, a subsidy was granted to shops and youth clubs participating in waste reduction and recycling;
- City officials implemented a city-wide direct personal public engagement with the residents to promote public participation in recycling; and

[68] Hotta, Y. and Aoiki-Suzuki, C. (2014), *Waste reduction and recycling initiatives in Japanese cities: Lessons from Yokohama and Kamakura*, Available at: https://www.ncbi.nlm.nih.gov/pubmed/25023986 (Accessed 31 May 2017).
[69] Ibid.

- As the 'Garbage Dieting' strategy was implemented nearly 20 years ago, the public started exhibiting signs of apathy and reduced participation, which led the city to reinforce its public campaigning and at the same time consider new waste reduction measures, such as charging residents based on the volume of waste that they generate.

Waste reduction and landfill diversion success

- Under the Law for the Promotion of Efficient Utilisation of Resources, 98% of metals are reused and recycled in industry;
- The success of the Food Waste Recycling Law allowed the Japanese food industry to reduce, reuse, and recycle an average of 82% of its food waste in 2010, just after nine years since its implementation;
- In Yokohama, the volume of municipal waste was reduced by 34% over the five-year period 2001 to 2005, attaining the 30% reduction goal over five years early;
- In Yokohama, the volume of municipal waste was reduced by 42% in 2010 compared to the baseline year of 2001; and
- In Kamakura, the initial success of the 'Garbage Dieting' waste reduction campaign enabled the Imaizumi incineration plant to be closed, and the city concurrently announced plans to halve the annual incineration volume to 35,000 tonnes.

Time factor based on Japan

Although a major success was noted in industrial food waste reduction in Japan, the quantity of food waste at the consumer stage has not shown any change in recent years[70]. However, given the stringent policy measures in Japan, such an approach could speed up HW reduction through the faster uptake of exchange platforms and sharing platforms.

Table 5 summarises the predicted uptake of each CE initiative if an approach closer to that of Japan is adopted. Please note that the time factors given in **Table 5**, have not been applied to the model in the **supplementary MS Excel document** and are only given as a guidance.

[70] Organisation for Economic Co-operation and Development (OECD) (2014), *Preventing Food Waste: Case Studies of Japan and the United Kingdom*, Available at: http://www.oecd.org/officialdocuments/publicdisplaydocumentpdf/?cote=TAD/CA/APM/WP(2014)25/FINAL&docLanguage=En (Accessed 02 June 2017).

Table 5: The predicted uptake for each CE initiative (Japan experience)

CE initiative	CDEW	C&IW	HW
Additive manufacturing	15 years (2031)	n/a	n/a
Modularity	5 years (2021)	n/a	n/a
Leased assets	15 years (2031)	10 years (2026)	15 years (2031)
Smart predictive maintenance	n/a	10 years (2026)	n/a
Urban analytics	10 years (2026)	10 years (2026)	15 years (2031)
Exchange platforms	10 years (2026)	10 years (2026)	15 years (2031)
Sharing platforms	n/a	10 years (2026)	15 years (2031)
Urban farming	n/a	n/a	10 years (2026)
Laser-etched branding	n/a	5 years (2021)	n/a

3.5 Circular Economy transition scenarios

3.5.1 Overview

Three CE scenarios were tested against the updated GLA model, including:

- Low CE uptake scenario – all CE initiatives will be implemented only to some extent (i.e. 'the conservative approach');
- Medium CE uptake scenario – all CE initiatives will be implemented to the best level that is currently thought to be technologically, financially, socially and environmentally feasible (i.e. 'the realistic approach'); and
- High CE uptake scenario – all CE initiatives will be implemented to the highest possible quantifiable uptake level (i.e. 'the ambitious approach').

The updated GLA model was treated as the 'business as usual' scenario, against which all waste reduction projections were tested.

The waste reduction projections of each scenario were estimated be up to the year 2041, which marks the end of the London Plan. These projections use baseline data that takes no account of other waste reduction assumptions used for land planning purposes i.e. the GLA's target of a 5% reduction in waste arisings by 2031 compared to 2016 waste arisings.

The scenarios take account of the time that may be required to implement the initiatives to the level appropriate to the scenario but do not go beyond full achievement of that level i.e. if full achievement is achieved in 2031 the value that represents full achievement applies from 2031 to 2041.

The CE initiatives considered in each scenario are independent of one another and no cumulative effect assessment is made as the interactions between the different initiatives are beyond the scope of this report.

3.5.2 Scenario 1 – Low CE uptake scenario

This is treated as the 'conservative approach' to the implementation of CE. Partial implementation is represented as a proportion of the highest maximum level. For the purposes of this study the maximum proportion is thought to be 25%. The chosen percentages for each CE initiative were based on the current barriers to the implementation of each CE initiative, which can be found in **Appendix C** and they are given in **Table 6**.

Table 6: Percentage reduction for low uptake scenario

CE initiative	CDEW fraction of high uptake scenario (max 25%)	C&IW fraction of high uptake scenario (max 25%)	HW fraction of high uptake scenario (max 25%)
Additive manufacturing	20%	-	-
Modularity	25%	-	-
Leased assets	20%	25%	25%
Smart predictive maintenance	-	25%	-
Urban analytics	25%	25%	15%
Exchange platforms	20%	20%	10%
Sharing platforms	-	15%	10%
Urban farming	-	-	10%
Laser-etched branding	-	25%	-

3.5.3 Scenario 2 – Medium CE uptake scenario

This is treated as the 'realistic approach' to the implementation of CE. Implementation to the best level achievable is represented as a proportion of the highest maximum level. For the purposes of this study the maximum proportion is 50%. The chosen percentages were based on the current barriers to the implementation of each CE initiative and they are given in **Table 7**.

Table 7: Percentage reductions for medium CE uptake scenario

CE initiative	CDEW fraction of high uptake scenario (max 50%)	C&IW fraction of high uptake scenario (max 50%)	HW fraction of high uptake scenario (max 50%)
Additive manufacturing	40%	-	-
Modularity	50%	-	-
Leased assets	40%	50%	50%
Smart predictive maintenance	-	50%	-
Urban analytics	50%	50%	30%
Exchange platforms	40%	40%	20%
Sharing platforms	-	30%	20%
Urban farming	-	-	20%
Laser-etched branding	-	50%	-

3.5.4 Scenario 3 – High CE uptake scenario

This is treated as the 'ambitious approach' to the implementation of CE. Implementation to the highest maximum level is represented by the percentage by weight reduction that our research shows each initiative might deliver for each of the three principal waste streams to which it is applicable (see **Table 2**). The level is indicated by the yellow highlighted percentage by weight reduction given for each initiative in **Appendix A**.

Table 8 is included in order to highlight that it was assumed that 100% uptake will be achieved for each targeted CE initiative under the high CE uptake scenario.

Table 8: Percentage reductions for medium CE uptake scenario

CE initiative	CDEW fraction of high uptake scenario	C&IW fraction of high uptake scenario	HW fraction of high uptake scenario
Additive manufacturing	100%	-	-
Modularity	100%	-	-
Leased assets	100%	100%	100%
Smart predictive maintenance	-	100%	-
Urban analytics	100%	100%	100%
Exchange platforms	100%	100%	100%
Sharing platforms	-	100%	100%
Urban farming	-	-	100%
Laser-etched branding	-	100%	-

4 GLA waste projections model

SLR Consulting Ltd (SLR) prepared a waste arisings model on behalf of GLA in order to inform the Further Alterations to the London Plan (FALP) publication[71]. The model includes CDEW, C&IW and local authority collected waste projections (LACW) (which is divided into HW and non-household LACW).

The model has since then been reviewed by SLR in order to compare actual waste arisings in London to the FALP forecasts of the 2014 SLR model. As a result, waste arisings projections have been modified by SLR and the new model (currently unpublished), proposes refinements to the original approach.

The updated model has also assessed the potential impacts of the GLA's CE objectives. The main CE effect that is accounted for in the updated GLA model, is a 5% reduction in HW and C&IW generation per person in 2031 relative to the 2015/16 baseline. However, to avoid any double counting, this 5% reduction was not included in the impact assessment undertaken in the present study (see **Section 5**).

The updated GLA model provides C&IW and HW arisings projections in tonnes per annum between 2016 and 2041.

[71] Greater London Authority and SLR Consulting (2014), *Waste Arisings Model: Further Alterations to the London Plan*.

5 Impact assessment

5.1 Calculations

The waste arisings projections quoted by SLR in their updated GLA model were used to test each CE uptake scenario.

Since the CE initiatives targeting C&IW and HW were aimed at specific waste streams, waste compositions for both C&IW and HW were obtained, in order to determine the contribution of each waste stream to the overall waste arisings.

The waste composition for both C&IW and HW was obtained from Defra[72]. It should be noted that for C&IW composition, only the commercial proportion was considered.

The relevant CE initiatives for each of the three types of waste (see **Section 3.3**), including the specific waste streams that they target, together with the waste reduction achieved for each waste stream (see **Section 3.3**) under each scenario (see **Section 3.5**), as well as the time factor *t* (see **Section 3.4**) were applied to the SLR data, for all the years between 2016 and 241.

The detailed calculations can be found in the **supplementary MS Excel document**.

5.2 Results

All the results are given as thousand tonnes per annum in five year increments between 2016 and 2041 (i.e. the London Plan period).

The summary results for all three scenarios can be found on **Table 9**.

Table 9: Summary results under each scenario

Year	Business as usual ('000 tonnes per annum)	Low uptake scenario ('000 tonnes per annum)	Medium uptake scenario ('000 tonnes per annum)	High uptake scenario ('000 tonnes per annum)
2016	**17,946**	**17,946**	**17,946**	**17,946**
2021	**18,575**	**17,570**	**16,564**	**13,861**
2026	**19,200**	**17,235**	**15,270**	**10,192**
2031	**19,820**	**17,154**	**14,487**	**8,157**
2036	**20,442**	**17,820**	**15,199**	**8,462**
2041	**21,063**	**18,123**	**15,183**	**8,050**

[72] Defra (2012), *Updated compositional estimates for local authority collected waste and recycling in England, 2010/11 - EV0801;* Available at: http://randd.defra.gov.uk/Default.aspx?Menu=Menu&Module=More&Location=None&Completed=0&ProjectID=18237 (Accessed 4 April 2017).

The detailed results, including waste arisings of different waste streams for each one of the three types of waste (CDEW, C&IW and HW) under each of the three scenarios are given in **the supplementary MS Excel document**.

5.2.1 CDEW

The waste arisings projections for CDEW under the different scenarios are given in **Figure 19**. The percentage reductions for CDEW achieved over the London Plan period under each scenario are given in **Figure 20**.

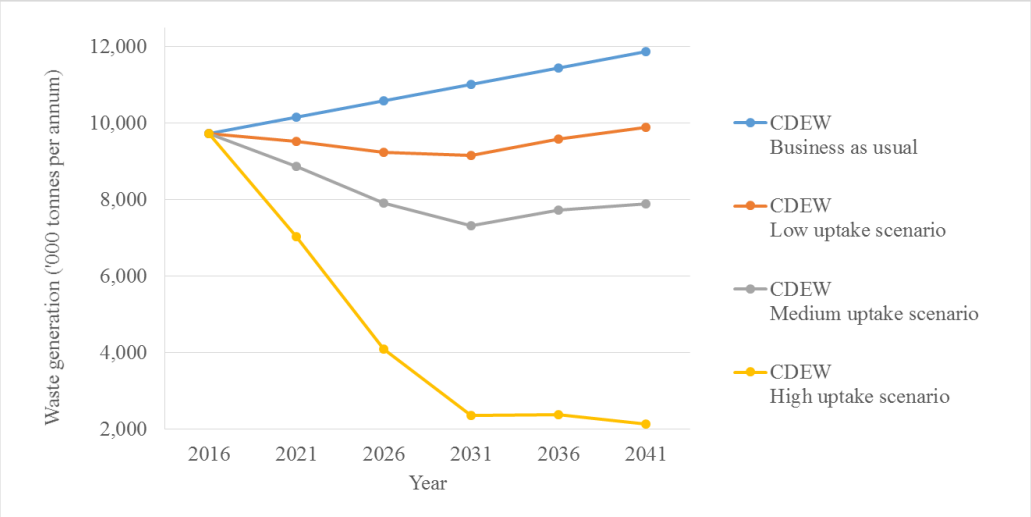

Figure 19: CDEW arisings projections under the different scenarios

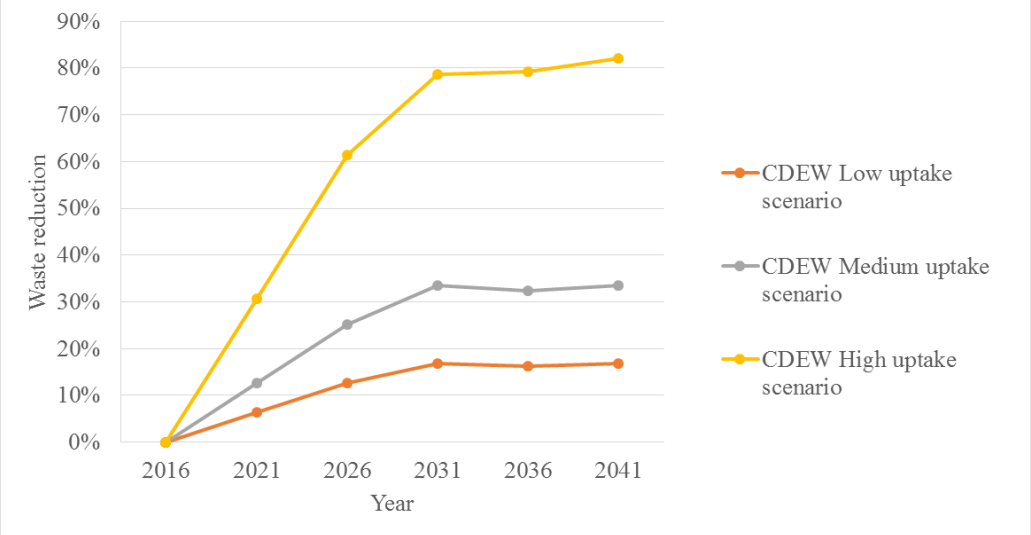

Figure 20: CDEW waste reductions under the different scenarios

5.2.2 C&IW

The waste arisings projections for C&IW under the different scenarios are given in **Figure 21**. The percentage reductions for C&IW achieved over the London Plan period under each scenario are given in **Figure 22**.

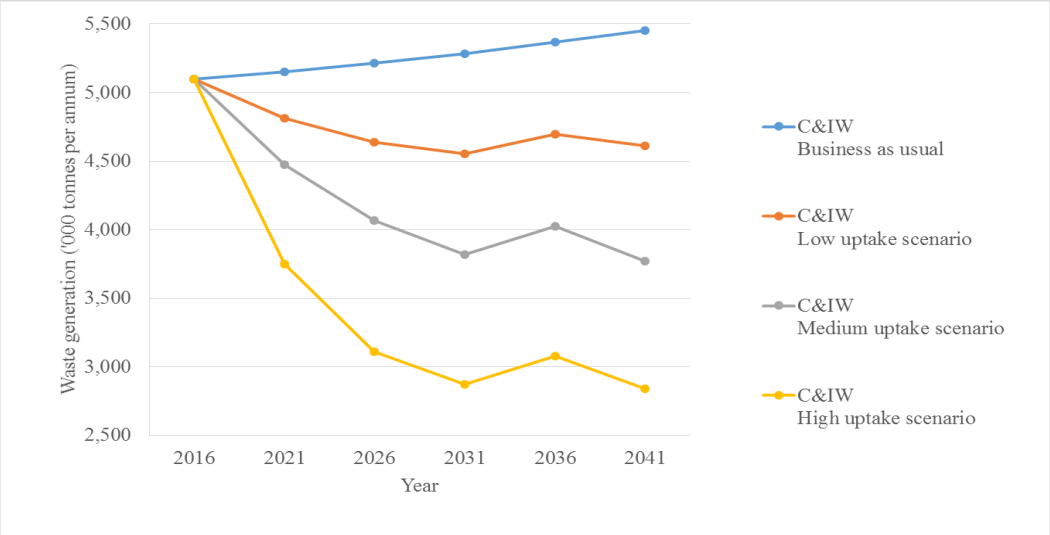

Figure 21: C&IW arisings projections under the different scenarios

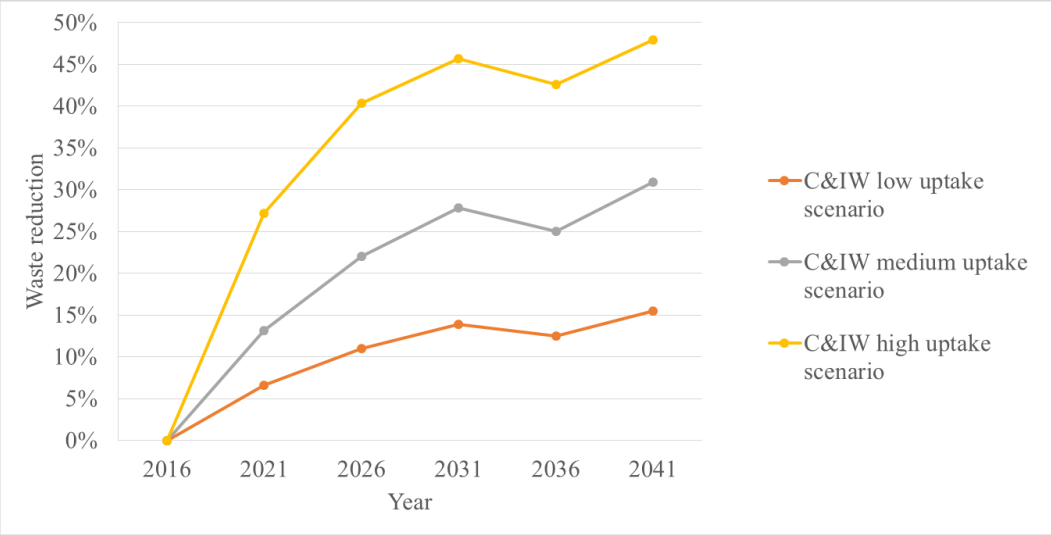

Figure 22: C&IW waste reductions under the different scenarios

5.2.3 HW

The waste arisings projections for C&IW under the different scenarios are given in **Figure 23**. The percentage reductions for HW achieved over the London Plan period under each scenario are given in **Figure 24**.

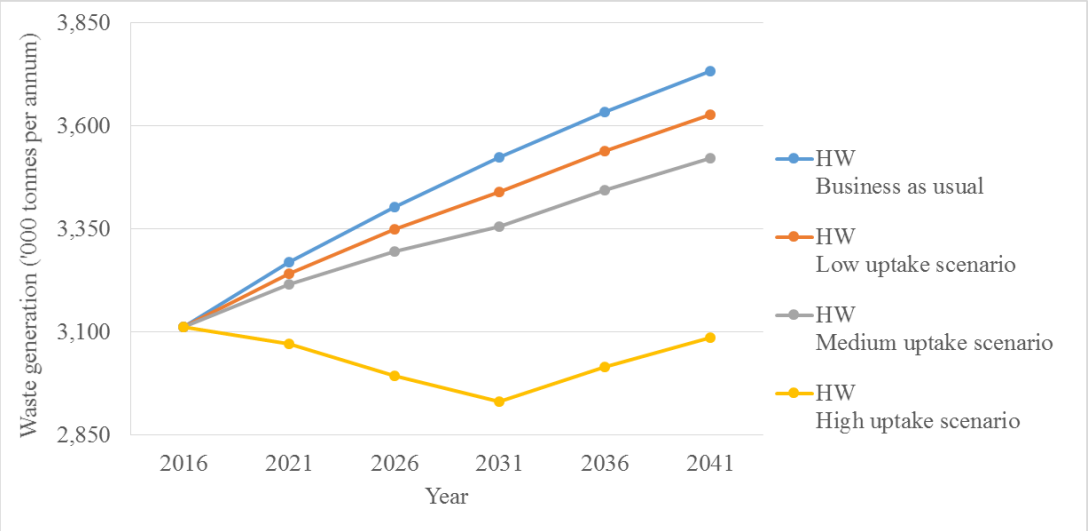

Figure 23: HW arisings projections under the different scenarios

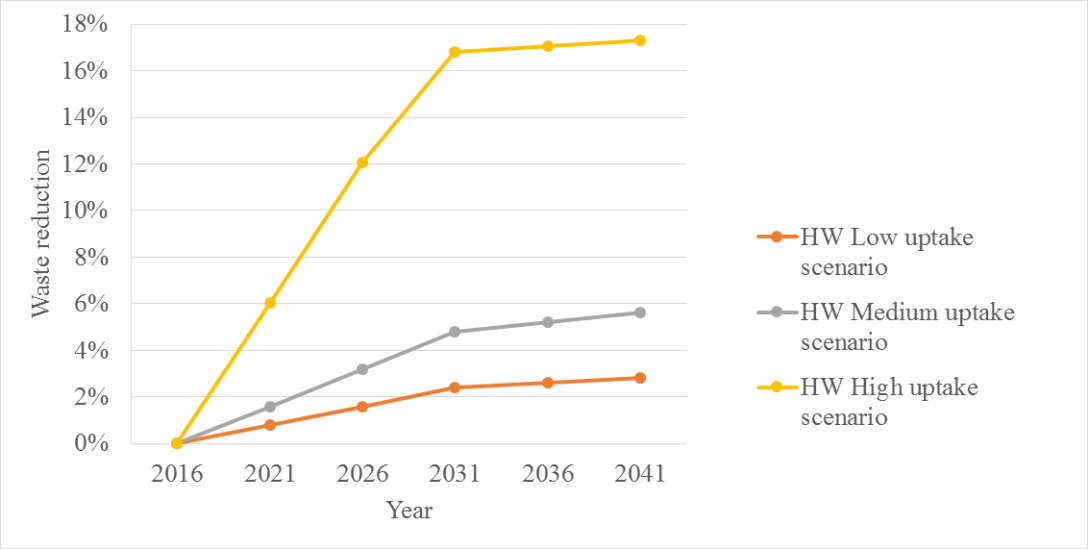

Figure 24: HW waste reductions under the different scenarios

6 Summary of findings

6.1 Change in total quantum

The total waste arisings for all three waste types combined (CDEW, C&IW and HW) are given in **Figure 25**. The total percentage reductions for all three waste types achieved over the London Plan period under each scenario are given in **Figure 26**.

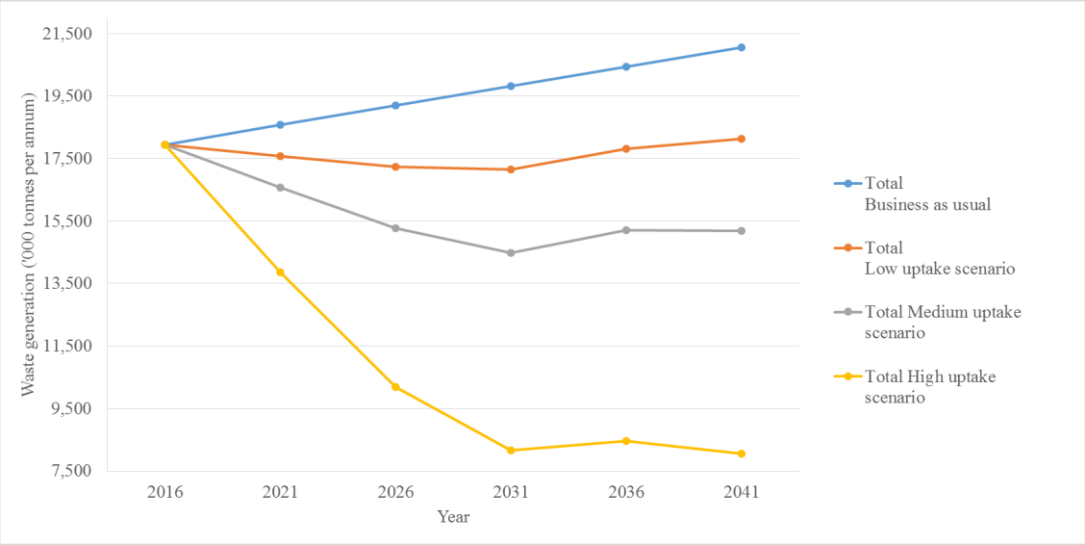

Figure 25: Total waste arisings projections under the different scenarios

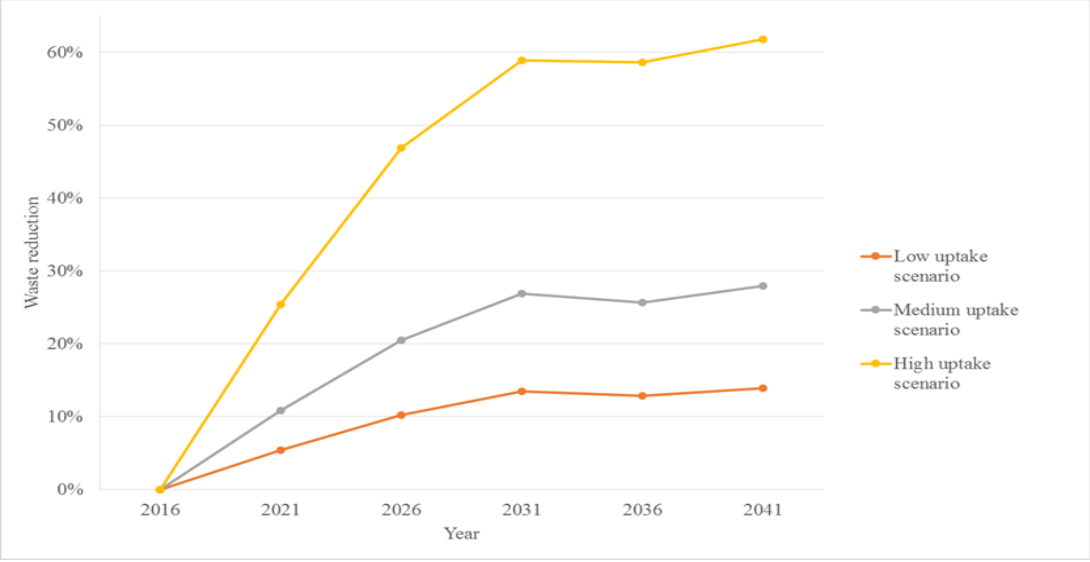

Figure 26: Total waste reductions under the different scenarios

7 Facilitating CE Initiatives

7.1 Overview

Most of the concepts, technologies, processes and products that constitute the nine chosen CE initiatives, are not novel. They have been around for a number of years and they have demonstrated a highly varied level of success.

For instance, several clothes rental and food sharing start-up companies have failed to take off, despite the fact that they have attracted thousands of users, many times surpassing initial expectations. The lack of success is the result of a combination of reasons, including:

1. Lack of public regulation;
2. Lack of government incentives;
3. Lack of appropriate infrastructure;
4. Limited availability of trained, specialised human resources;
5. Strong competition from many similar start-ups;
6. Reluctance of moving away from traditional business models;
7. Lack of collaboration between business sectors and stakeholders; and
8. Lack of circular economy and general environmental awareness.

As a result, three further initiatives that can play a key role in the implementation and success of the nine CE initiatives, identified in this study, are outlined below.

7.2 Strategic public engagement

Well-targeted business and public engagement is key to the success of all CE initiatives. Engagement is by definition a two-way process, involving interaction and listening, with the goal of generating mutual benefit[73].

In a survey undertaken by Go Circular, effective communication strategies were cited by the vast majority of respondents (83%) as being an 'extremely important' driver in terms of deepening engagement levels with the CE agenda, with a further 16% regarding it as 'fairly important'[74]. In order to achieve lasting, meaningful impact, it is vitally important to strategically engage a broad range of public bodies, businesses, associations, researchers, and the general public. Public engagement must move beyond an initiative/project phase, to become an evolving

[73] National Co-ordinating Centre for Public Engagement (NCCPE), *What is Public Engagement?;* Available at: https://www.publicengagement.ac.uk/explore-it/what-public-engagement
[74] Perella, M. (2015), *Communicating the Circle;* Available at: http://www.gocircular.com/uploads/5/0/6/3/50632287/communicating_the_circle.pdf (Accessed 4 April 2017).

set of sustainable practices and habits among leaders and the public that become embedded in the life of the community[75].

A range of innovative communications strategies and outreach activities can build levels of awareness, understanding and support for the CE. Public engagement on CE initiatives should be infrastructure and system specific and well-targeted to achieve success.

At the regional level, so-called 'living labs' provide an opportunity for an interactive communication amongst entrepreneurs, scientists, policy-makers and citizens in order to find concerted solutions to common needs in terms of strategy development[76]. University of Cambridge's 'Living Lab' provides opportunities for students to improve environmental sustainability on the University estate through projects, internships and research[77].

Thematic workshops on CE initiatives in the community centres, schools and universities could be used to draw citizen's attention and raise awareness of the bio-economy amongst current generation.

Exhibitions can be an effective means to explain to the general public about CE initiatives and its benefits. At the same time, they can also be used to initiate a dialogue with visitors, e.g. by means of a survey that explores the visitors' views on the benefits and challenges related to the development of CE strategies.

Community conversations, 'study circles', focus groups, online engagement strategies and media partnerships are a few of the other possibilities. For example, community groups should identify when new-householders move into an area, and inform them about the sustainable initiatives adopted in the neighbourhood to them as an induction. Adopting rooftop farming amidst flat-dwellers can create a community spirit whilst reducing packaging waste and simultaneously meeting the residents fruit and vegetable demands.

The role of young people is particularly important if CE models of production and consumption are to become the norm over time. Leased assets such clothes renting, exchange platforms for food and products can be popularised on social media attracting the younger generation. Shared communal working spaces and facilities should be made available to students, graduates and start-up companies to work. This moves away from the traditional make-use-dispose approach to goods towards methods of keeping them in high value use for as long as possible. For example, textile agency Kalopsia shares its facility and equipment with young professionals[78].

[75] Centre for Advances in Public Engagement (2008), *Public Engagement: A Primer from Public Agenda*, Available at:
https://www.publicagenda.org/files/public_engagement_primer.pdf
[76] BioSTEP (2017), *Creating Networks for the Transition to a Bio-based and Circular Economy*, Available at:
http://www.bio-step.eu/fileadmin/BioSTEP/Bio_documents/BioSTEP_Policy_Paper_Draft.pdf
[77] University of Cambridge, *Living Laboratory for Sustainability*, Available at:
https://www.environment.admin.cam.ac.uk/living-lab (Accessed 6 April 2017).
[78] Kalopsia (2017), Available at: http://contemporarytextile.com/ (Accessed 6 April 2017).

The power of attaching a value to goods previously seen as disposable would engage the public and help them to understand their responsibilities as citizens[79]. For example, the carrier bag charge sparked high levels of public engagement across the country.

7.3 Community-led development

Community-led development allows local people to oversee the design and construction of their own homes and communities to a particular specification. Research suggests that, where residents and landlords work together, new housing is more likely to meet the needs of the community and create a place that residents feel proud of.

If a place is appealing to future generations, there is a long-term sustainability benefit which avoids the expense and waste associated with rebuilding homes[80].

Urban Splash property developers[81] have worked together with residents in Manchester in order to design their modular homes in a way that adheres to the needs of the residents. The open design choice for residents became possible because of the modular design of all the houses of the new development. New residents could choose whether they wanted a 1,000ft^2 –two storey house or a 1,500ft^2-three storey house. They could also choose whether they wanted to live on the ground floor or first floor and then decide how they wanted to occupy the rest of the house.

7.4 Social impact monetisation

Social investments are investments made with the intention to generate social and environmental impact alongside a financial return. Impact investments target financial returns that range from concessionary to risk-adjusted market rate, and can be made across asset classes, including, but not limited to, cash equivalents, fixed income, venture capital, and private equity.

Services which have managed to provide a concrete monetisation methodology have gained the most attraction from investors and clients. A promise of social impact is the commitment of the service provider to measure and report the social and environmental performance and progress of underlying services. This ensures transparency and accountability, avoiding explicit 'green washing', while also informing the practice and building the field. Investors' approaches to impact measurement will vary based on their objectives and capacities, and the choice of what to measure usually reflects investor goals and, consequently, investor intention.

[79] Scottish Government, *Making Things Last – A Circular Economy Strategy for Scotland;* Available at: http://www.gov.scot/Publications/2016/02/1761/15 (Accessed 6 April 2017).
[80] Design council (2017), *Community-led development;* Available at: http://www.designcouncil.org.uk/what-we-do/community-led-design-development (Accessed 16 March 2017).
[81] Urban Splash (2014), hoUSE, Available at: http://www.urbansplash.co.uk/residential/house (Accessed 19 April 2017).

Three ways in which social impact monetisation can be applied include[82]:

1. Waste reduction investment - rewards schemes motivate construction parties to increase their participation in waste reduction schemes;
2. The government should encourage design organisations' environmental performance through a more targeted certificate that can comprehensively assess the potential of design in waste reduction and through a bonus scheme, which also translates to extra waste investment; and
3. Economic incentive - rewarding (and penalizing) project stakeholders, especially architects, for their waste reduction performance.

[82] Wang *et al* (2014), *Critical factors in effective construction waste minimization at the design stage: A Shenzhen case study, China*, Resources, Conservation and Recycling: 82, 1-7

8 Future CE initiatives to target holistic resource management

8.1 Overview

Longer-term initiatives, that address different parts of the resource and waste management system (including reuse, recycling, and recovery) have been identified, as these can create an opportunity for making use of some of the safeguarded waste management sites in London in the future.

8.2 Planned obsolescence elimination

Planned obsolescence or built-in obsolescence in industrial design and economics is the policy of production of goods with a deliberate and uneconomical short predetermined period so that consumers will demand replacements in the future[83]. In some instances, this motivates multiple sales of the same object to the same consumer[84]. Obsolescence can also be achieved through introduction of a superior replacement or a product design meant to cease proper function within a specific window, or by cultivating desirability of new versions over older ones. For example, proprietary screws on Apple products often prevent Apple consumers from opening Apple devices at all. It is standard practice for companies to plan obsolescence into their products including by introducing software upgrades that are not compatible with existing hardware, and they simultaneously profit from the fact that the average laptop has a high likelihood of breaking within 3-4 years.

Due to a lack of clear economic incentives and methods, globally only 12% of smartphone upgrades involve older devices being sold or traded for the new one[85]. This means ecologically damaging electronic devices end up languishing in storage boxes and eventually in landfills, thereby becoming an issue in implementing any CE initiatives.

CE initiatives would require tackling planned obsolescence by a pay-as-you-throw waste tax, a tax on disposable products, ensuring better, durable product design, providing useful consumer information, technical standardisation to the benefit of the consumer, exchange of worn-out products for a new product and reparability of products using 3D printing methods.

[83] Bulow, J (1986), *An Economic Theory of Planned Obsolescence*, The Quarterly Journal of Economics, 101:**4**, 729-749.
[84] Investopedia. *Planned Obsolescence;* Available at: http://www.investopedia.com/terms/p/planned_obsolescence.asp (Accessed 5 April 2017).
[85] Spinks, R (2015), *We're all losers to a gadget industry built on planned obsolescence*, The Guardian; Available at: https://www.theguardian.com/sustainable-business/2015/mar/23/were-are-all-losers-to-gadget-industry-built-on-planned-obsolescence (Accessed 5 April 2017).

France was the first country to outlaw built-in obsolescence and make it punishable by two years of prison or €300,000 Euro fine[86]. At the European level, both the European Economic and Social Council and the European Consumer Association have pushed this issue up on their agendas and hosted a series of workshops and conferences since 2013, both actively supporting legally binding measures to ban built-in obsolescence.

When one component breaks or wears down, the entire product with all its residual value is generally discarded before the end of its natural lifetime. Products should be designed to wear out evenly. For example, an apparel producing company, Patagonia, designs its garments so that they do not need to be taken apart completely if, for example, a zipper were to fail. They produce high–quality, responsibly sourced clothing that lasts for years and can be repaired and is guaranteed it for life[87]. They provide free repair guides online to provide customers with opportunities to fix their gear themselves, find it a new home or recycle it if necessary.

Caterpillar remanufactures parts and components that provide same-as-new performance and reliability at fraction-of-new costs[88]. Their remanufacturing programme is based on an exchange system where customers return a used component in return for our remanufactured products and their over the counter availability gives customers more options at repair and overhaul time.

8.3 Reverse logistics

This approach requires control to be maintained over materials and products throughout their lifecycle to ensure they keep re-entering the product or service economy. This can be done using effective storage, collection and transport systems that enable the capture of valuable resources, and can take the form of recycling on-the-go and multi-modal transport (road, rail, water), among others.

8.4 Autonomous road logistics

Wireless waste monitoring systems are smart waste collection systems that use a wireless sensor network and online system to gather fill level data from waste containers. This is then used to generate an optimised waste collection schedule as well as an optimised collection route to take by waste collection vehicles.

[86] Wieser, H (2016), *Beyond Planned Obsolescence: Product Lifespans and the Challenges to a Circular Economy*, GAIA, 25(3): 156-160; Available at: https://www.academia.edu/29447950/Beyond_Planned_Obsolescence_Product_Lifespans_and_the_Challenges_to_a_Circular_Economy (Accessed 5 April 2017).
[87] Pantagonia, (*no date*), *The stories we wear*, Available at: http://eu.patagonia.com/enGB/worn-wear/ (Accessed 5 April 2017).
[88] Caterpillar (2017), *The Benefits of Remanufacturing*, Available at: http://www.caterpillar.com/en/company/sustainability/remanufacturing/benefits.html (Accessed 5 April 2017).

8.5 Robotic waste collection systems

Various robotic waste collection systems have been developed that assist with safe and efficient waste collection services to avoid the need for humans to perform heavy lifting and potentially dangerous tasks.

8.6 Remanufacturing RCVs

Due to poor maintenance of refuse collection vehicles (RCVs), their service life can be unnecessarily reduced. By entering into a business model that sees their periodic repair and remanufacture, their lifecycle can be extended. As an alternative to procuring new RVCs, minor or major modifications can be made to existing fleets in the form of specialist preventative repairs and maintenance services to extend the service life of an RCV (often five to seven years). Repair and remanufacturing can be a cost-effective and resource efficient solution.

8.7 Mycelium biomaterials

Building materials made from mycelium, a type of fungus, have more insulating power than fiberglass. In addition to this, mycelium is completely biodegradable, which enables a closed loop model. Mycelium (the roots of fungi) convert hydrocarbons into carbohydrate chains and, in the process, wrap themselves tightly around any surface they touch. When introduced to a material such as agricultural crop waste, canola and wood, the mycelium quickly digests all the available lignin and encapsulates the remaining material components to produce a solid material that can be used as packaging materials or in the manufacture of construction boards. Mycelium grows underground in the absence of light and therefore does not require any external energy source to grow. The materials made using mycelium are 100% biodegradable, which present a close loop opportunity. Under controlled conditions, mycelium packaging can be produced within one week.

8.8 PVC recycling

Polyvinyl chloride (PVC) is one of the most common plastics in use accounting for 20% of all plastic manufactured worldwide. It is 100% recyclable with different recycling technologies used for different purposes. As a valuable and finite resource, the optimum recovery route for PVC at end-of-life is recycling, ideally into a product that also has the ability be recycled.

8.9 Paper cup recycling

Paper cup recycling can be challenging since the paper is usually fused with polyethylene. There are only a small number of specialist fibre recovery facilities that are able to recycle paper cups, leaving space for new players to enter the market. Separate to this, there is a potential opportunity to rethink the supply chain of paper cups and develop a closed loop business model for a new paper cup product.

8.10 Carbon fibre recycling

As an increasing number of products use carbon fibre and carbon fibre composites, technologies that are able to effectively and economically recycle these materials will be essential. The most common recycling process currently uses pyrolysis.

8.11 Plastic depolymerisation

Plastic depolymerisation technology uses heat and sometimes catalysts to break long-chain polymers into shorter-chain compounds, which can subsequently be used in oil products, such as fuels. For low-grade mixed waste plastics, this presents an opportunity to make beneficial use of an unrecyclable material that may have otherwise ended up in landfill or in the marine environment.

Appendix A

Waste reduction assumptions

A1 Additive manufacturing

The % reductions shown in yellow are the ones chosen to be used in the scenario formulation and impact assessment.

CDEW

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
Construction-scale additive manufacturing (3D printing) (e.g. concrete printing)	All construction materials (metals, plastic, ceramics, glass, wood)	A high-performance cement-based mortar has been developed for Concrete Printing which comprises 54% sand, 36% reactive cementitious compounds and 10% water by mass. 3D printing only uses product as needed so no waste it cumulated WinSun says the 3D process saves between 30% and 60% of construction waste Average: (30+60)/2= 45%	45	1.https://www.cnet.com/news/worlds-first-3d-printed-apartment-building-constructed-in-china/
Digitial Fabrication/ Direct Digital Manufacturing (CNC machining)	All construction materials (metals, plastic, ceramics, glass, wood)	Typically, shapes are cut out of wooden sheets Factory production lines using CNC machines for accurate cutting, aligning, screwing, nailing, painting and handling etc drastically	95	1.http://www.zendergroup.org/docs/cand.pdf, http://ac.els-cdn.com/S0959652616304395/1-s2.0-S0959652616304395-main.pdf?_tid=a6c71810-0ff8-11e7-add6-00000aab0f6c&acdnat=1490294808_fd80747988f6e693d2a6f88bb

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
		reduce waste materials. What waste is produced is controlled and recycled. Material losses have been reduced to 5% of those seen using traditional methods and materials, further serving to reduce post-processing operations.		4a490c32.http://ac.els-cdn.com/S0959652615005429/1-s2.0-S0959652615005429-main.pdf?_tid=686ea27c-0ff8-11e7-8609-00000aab0f01&acdnat=1490294703_bcaa0648c87cb04f4038732ce3152b3e

A2 Modularity

The % reductions shown in yellow are the ones chosen to be used in the scenario formulation and impact assessment.

CDEW

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
Prefabrication	Timber	-	80.5	1.http://www.sciencedirect.com/science/article/pii/S0360132306002873
Prefabrication	Concrete	-	55.5	1.http://www.sciencedirect.com/science/article/pii/S0921344913002309
Prefabrication	Concrete	-	90 (by area)	1.http://www.sciencedirect.com/science/article/pii/S0360132306002873

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
Prefabrication	Reinforcement works	-	92	1.http://www.sciencedirect.com/science/article/pii/S0360132306002873
Prefabrication	Plastering	-	100 (by area)	1.http://www.sciencedirect.com/science/article/pii/S0360132306002873
Prefabrication	Tiling	-	74 (by area)	1.http://www.sciencedirect.com/science/article/pii/S0360132306002873
Modular design	Carpet tiles	-	88	1.http://www.wrap.org.uk/sites/files/wrap/InterfaceFLOR%20WRAP%20case%20study%20FINAL.pdf
Upstream process (i.e. off-site prefabrication)	All construction materials (metals, plastic, ceramics, glass)	-	10% (by achieving a wastage of 2%)	1.http://ac.els-cdn.com/S1364032113005881/1-s2.0-S1364032113005881-main.pdf?_tid=108533e8-0b0a-11e7-b142-00000aab0f6c&acdnat=1489752531_3eb456c21744617328db568e8e075de5
Downstream process (i.e. precise components onsite assembly)	All construction materials (metals, plastic, ceramics, glass)	-	4.5	1.http://ac.els-cdn.com/S1364032113005881/1-s2.0-S1364032113005881-main.pdf?_tid=108533e8-0b0a-11e7-b142-00000aab0f6c&acdnat=1489752531_3eb456c21744617328db568e8e075de5
Overall prefabrication effects on whole lifecycle	All construction materials (metals, plastic, ceramics, glass)	-	6.5	1.http://ac.els-cdn.com/S1364032113005881/1-s2.0-S1364032113005881-main.pdf?_tid=108533e8-0b0a-11e7-b142-00000aab0f6c&acdnat=1489752531_3eb456c21744617328db568e8e075de5

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
Overall reduction of site waste	Overall site waste	-	70	1.http://www.designforhomes.org/wp-content/uploads/2012/03/ModularSteel.pdf
Prefabrication	Overall site waste	Based on an assumption of up to 84.7% reduction of wastage	100	-

A3 Leased assets

The % reductions shown in yellow are the ones chosen to be used in the scenario formulation and impact assessment.

CDEW

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
Façade leasing	All construction materials (metals, plastic, ceramics, glass)	22 Ganton Street, London: 80% of the façade retained Assuming façade makes up 20% of the building infrastructure	16	1.http://www.betterbuildingspartnership.co.uk/shaftesbury%E2%80%99s-sustainable-retrofit-22-ganton-street 2.http://www.wrap.org.uk/sites/files/wrap/Refurbishment%20Resource%20Efficiency%20Case%20Study_Office_Unilever%20House.pdf

C&IW

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
Selling resource management instead of waste disposal in manufacturing	Scrap metal & Plastic	25% per vehicle: assumed that this is the case for other metal-based products	25	1.http://www.europarl.europa.eu/RegData/etudes/etudes/join/2012/492460/IPOL-ENVI_ET(2012)492460_EN.pdf
Chemical leasing for cleaning operations	Hazardous waste	Hazardous waste reduction: 94% PERC solvent reduction: 90%	92	1.https://europa.eu/eyd2015/en/unido/stories/business-model-chemical-industry-circular-economy-works, https://www.theguardian.com/sustainable-business/2014/dec/09/chemical-leasing-ecolab-coke-ikea-gm-un-cleaning-environment 2.http://ac.els-cdn.com/S0921344914000482/1-s2.0-S0921344914000482-main.pdf?_tid=68504102-1574-11e7-a6f9-00000aacb362&acdnat=1490897716_f87febb240881aab12db3502757393fc
Battery leasing	Batteries	Most EV batteries are guaranteed for 8 years or 160,000km (100,000 miles) EV's life expectancy: 400,000 miles i.e. 643,737.6km Ratio: 160,000km/643,737.6km=4 Weight of electric battery: 294kg	25	1.http://www.nextgreencar.com/electric-cars/statistics/, http://batteryuniversity.com/learn/article/electric_vehicle_ev 2.https://www.driving.co.uk/car-clinic/what-do-you-need-to-know-before-buying-a-used-electric-car/

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
		Waste if EV battery is discarded 4 times throughout its lifetime: 1176kg % waste reduction if leased and returned back to manufacturer per EV: 25%		
Car leasing	Cars	Average time of car ownership: 6.5 years Average car life expectancy: (8+15)/2= 11.5 years (assumed that by lease model, the maximum car life expectancy will be achieved) Average car weight: 1,850.2kg 3,700kg if car changed once before 11.5 years (1,850.2kg *2) So, double the weight is needed per car user	50	1.http://content.tfl.gov.uk/technical-note-12-how-many-cars-are-there-in-london.pdf

HW

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
Textiles (jeans)	Jeans	Extending the average life of clothes by just three	7.5	1.http://www.recyclefornorfolk.org.uk/get-involved/clothes-textiles/

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
		months of active use would lead to a 5-10% reduction in each of the carbon, water and waste footprints Assuming the average of this is the % reduction achieved		
Clothes renting applications (e.g. Rent the Runway)	Clothes	Extending the life of clothing by an extra nine months of active use would reduce carbon, waste and water footprints by around 20-30% each and cut resource costs by 20% It is assumed that extra nine months is representative, as such applications, target high-profile clothes, which is what customers are seeking. Thus, customers may not want to rent out clothes that were in fashion one year (or more) ago. The higher end of the range is chosen, as	30	1.http://www.recyclefornorfolk.org.uk/get-involved/clothes-textiles/ 2.http://www.wrap.org.uk/sustainable-textiles/valuing-our-clothes%20

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
		the actual extended life of the item may be slightly more than nine months (e.g. a year)		
Household tasks (garden maintenance, home improvement (e.g. setting up shelves), house cleaning (vacuum cleaning), laundry) (per household)	Household waste	0.345% waste reduction per household on average	0.345	1.https://dspace.lib.cranfield.ac.uk/bitstream/1826/8630/1/Annika_Gottberg_Thesis_2012.pdf 2.https://www.london.gov.uk/sites/default/files/housing_in_london_2015.pdf
Washing machine lease model (e.g. Bosch Siemens Hausgerate)	Washing machines	14% of washing machines replaced while they are still in working condition Assuming 0% will be discarded before their end-of-life The average washing machine contains about 40kg of steel and when a machine is scrapped, a proportion of the steel is lost to landfill. The exact figure is contested, but the loss is probably between 40% and 70%.	14	1.https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/274778/9_Domestic_appliances__cooking_and_cooling_equipment.pdf, https://www.ellenmacarthurfoundation.org/circular-economy/interactive-diagram/in-depth-washing-machines 2.http://www.bbc.co.uk/news/science-environment-21804935

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
Leased mobile phones	Mobile phones	Average phone lifespan: 4.7 years Average frequency people exchange their phones: 1.5 years Proportion of adults who personally own/use a mobile phone in the UK: 93% Adult population (over 16) of UK: 65,110,000 *0.78 Adult population (over 16) of UK with a phone: 47,230,794 Total phones in 5 years if exchanged every 4.7 years: 50,245,526, Total phones in 5 years if exchanged every 1.5 years: 157,435,980 % reduction in discarded mobile phones: 1-[(47,230,794/ 157,435,980)*100]= 70%	70	1.https://www.cta.tech/News/Blog/Articles/2014/September/The-Life-Expectancy-of-Electronics.aspx 2.https://www.ofcom.org.uk/about-ofcom/latest/media/facts

A4 Smart predictive maintenance

The % reductions shown in yellow are the ones chosen to be used in the scenario formulation and impact assessment.

C&IW

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
Improved inventory management (computerised maintenance management system (CMMS))	Electrical and Electronic Equipment (EEE)	17.8% reduction in maintenance, repairs, operation (MRO) inventory	18	1.https://energy.gov/sites/prod/files/2013/10/f3/OM_4.pdf 2.http://www2.emersonprocess.com/siteadmincenter/PM%20Central%20Web%20Documents/plantweb-ops-maint.pdf
Improved inventory management (GS1 standards, barcodes scanned at any time of the supply chain)	Packaging materials (plastics, cardboard, wood) and paper	Reducing stock in multiple hospital wards by 20%, and waste to less than 1% Approximated by Health care & biological wastes: 167,202 tonnes 2014 commercial waste: 15,100,000 tonnes (167,202 tonnes/15,100,000 tonnes)*100= 1.11%	0.0022	1.https://www.gs1uk.org/~/media/documents/marketing-documents/gs1_uk__portsmouth_casestudy.pdf 2.https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/601470/Digest_of_Waste_and_Resource_Statistics__2017.pdf
Planned, built-in obsolescence prevention	Electrical and Electronic Equipment (EEE)	In a survey performed as part of the study, 75% of consumers stated that the desire for a better device was integral to their decision to buy a new	83	1.http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Waste_electrical_and_electronic_equipment_(WEEE),_total_collected,_by_EEE_category,_2013.png 2.http://www.umweltbundesamt.de

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
		product, including products such as household appliances. Research revealed that the amount of household appliances replaced within five years due to defects increased from 3.5% in 2004 to 8.3% in 2013. The report includes investigations of consumer behaviour, replacement patterns and causes of defects across four product groups: large household appliances; small household appliances; information and communication technology and consumer electronics. A combination of consumer behaviour and defects: 75% + 8.3%= 83.3% Assuming "built-in" obsolescence and consumer behaviour obsolescence can be tackled 100%		/en/press/pressinformation/lifetime-of-electrical-appliances-becoming-shorter

A5 Urban analytics

The % reductions shown in yellow are the ones chosen to be used in the scenario formulation and impact assessment.

CDEW

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
Lean thinking application to construction waste (to achieve wastage and loss free processes and workflows)	All construction materials (metals, plastic, ceramics, glass)	Only five types of waste represent 80% of the referenced occurrence of waste in Virtual Design and Construction (VDC) processes, which suggests that if teams use Lean Methods and focus on elimination of these types of waste (i.e., motion (excess), inventory (excess), overproduction, waiting and employee knowledge (unused)), teams can improve VDC practices dramatically. Research indicates a wide variation in wastage rates of between 5%-27% of total materials purchased for construction projects The amount of direct waste by weight ranged	32	1.http://ir.knust.edu.gh/bitstream/123456789/3992/1/Final.pdf

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
		between 1 and 10% in weight of the purchased amount of materials. Assuming all of it can be eliminated by lean construction		
Building Information Modelling (BIM) applied to construction applications (e.g. energy simulation, sustainability, facilities management, risk management, cost estimation)	All construction materials (metals, plastic, ceramics, glass)	In Finland, BIM adoption in housing projects has led to the following benefits: waste reduction of 45%	45	1.http://ac.els-cdn.com/S2215098616309156/1-s2.0-S2215098616309156-main.pdf?_tid=937e9a0c-0fd1-11e7-8163-00000aacb35d&acdnat=1490278025_8ac30dd7301b23c5eb0bcba8c35de1f2

C&IW

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
Waste tracking and analytics applied by restaurants and food service providers - Mobile applications (e.g. Leloca)	Food	Using Leloca, businesses can instantly configure and control multiple real-time, geotargeted offers to nearby customers. Total retail & wholesale food waste: 300,000 tonnes Avoidable food waste: 300,000 tonnes Assuming 100%	24	1.http://www.refed.com/solutions/waste-tracking-and-analytics, https://www.leloca.com/about-us.html, http://www.wrap.org.uk/content/food-waste-hospitality-and-food-service-sector-0 2.http://www.wrap.org.uk/sites/files/wrap/Restaurants.pdf

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
		reduction in avoidable food waste from retail Total food waste from commercial sectors: 0.3 (retail)+ 1.7 (manufacturing)+ 0.9 (hospitality and food service) EAT managed a 14% reduction in waste food through better stock analysis Average of 10%-14%= 12% (just food) Getting the right volume into stores at the right time --> can translate into waste reductions of up to 35% (general) Average of (just food) and (general)= (12+35)/2= 23.5%=24%		
Waste tracking and analytics applied by/on behalf of retailers (e.g. Waste tracking.com)	Packaging materials (plastics, cardboard, wood) and paper	Getting the right volume into stores at the right time: can translate into waste reductions of up to 35%	35	1.http://www.oliverwyman.com/content/dam/oliver-wyman/global/en/2014/jul/OW_Reducing_Food_Waste.pdf
Installation of sensors in household wheeled bins to inform strategic	Cars	80% less emptying trips % reduction from total number RCVs assumed	80	1.http://www.wastetracking.com/solution-retail.html

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
waste reduction campaigns				

HW

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
Mobile applications for meal planning/making most of food available at home (e.g. 222 million tons, Pepperplate)	Food	Total household food waste: 7,300,000 tonnes Avoidable food waste: 4,400,000 tonnes – 5,700,000 tonnes (average is used) Assuming 100% reduction in avoidable food waste % reduction of food waste assuming 5,050,000 tonnes of avoidable food waste % reduction: (5,050,000 tonnes/7,300,000 tonnes)*100= 69.18%	69	1.https://foodtank.com/news/2015/01/twenty-three-mobile-apps-changing-the-food-system/
Installation of sensors in household wheeled bins	Plastics, food, paper, cardboard, glass	Real-time, continuous and accurate data from each household, can inform strategic waste reduction campaigns, and so they can be more targeted and thus,	-	-

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
		more effective in reducing general household waste		

A6 Sharing platforms

The % reductions shown in yellow are the ones chosen to be used in the scenario formulation and impact assessment.

C&IW

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
Surplus food sharing mobile applications (e.g. OLIO) used by supermarkets (including large chains, such as Sainsbury's)	Food	Total retail & wholesale food waste: 300,000 tonnes Avoidable food waste: 300,000 tonnes Assuming 100% reduction in avoidable food waste from retail Total food waste from commercial sectors: 0.3 (retail)+ 1.7 (manufacturing)+ 0.9 (hospitality and food service)	10	1.http://resource.co/article/food-redistribution-app-olio-expands-household-products-brexit-boom-boosts-secondhand-market

HW

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
Giving, swapping	Textiles, furniture, recreational facilities, electrical equipment, books, CDs/DVDs	If sharing models could be operated under the most favourable conditions, savings of up to 7% in the household budget and 20% in terms of waste could be achieved (assumed 20% is total reduction through combination of textiles, furniture, books and electrical equipment)	20	1.http://www.iddri.org/Evenements/Interventions/ST0314_DD%20ASN_sharing%20economy.pdf
Unwanted home items sharing mobile application (e.g. OLIO)	Hard plastics	Typical child uses only 5% of its toys (so rest could be shared): 95% Assuming that just under half of the items given away are toys: 40%	40	1.http://www.telegraph.co.uk/finance/newsbysector/retailandconsumer/8074156/Ten-year-olds-have-7000-worth-of-toys-but-play-with-just-330.html 2.http://www.frn.org.uk/documents/FRN%202009%20Final%20average%20weights%20list.pdf
Surplus food sharing mobile applications (e.g. OLIO)	Food	Total household food waste: 7,300,000 tonnes Avoidable food waste: 4,400,000 tonnes – 5,700,000 tonnes (average is used) Assuming 100% reduction in avoidable food waste % reduction of food waste assuming 5,050,000 tonnes of	69	1.http://resource.co/article/food-redistribution-app-olio-expands-household-products-brexit-boom-boosts-secondhand-market

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
		avoidable food waste % reduction: (5,050,000 tonnes/7,300,000 tonnes)*100= 69.18%		

A7 Urban farming

The % reductions shown in yellow are the ones chosen to be used in the scenario formulation and impact assessment.

HW

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
Urban agriculture projects (e.g. Community Supported Agriculture (CSA))	Packaging waste (plastics)	Average person - 600kg of food with 160kg packaging. If fruits, veg, dairy and meat are purchased through CSA, that saves approx 80kg packaging (approx 50%) Manufacture of food products, beverages and tobacco products tonnes: 121,012 tonnes (according to EA 2015 spreadsheet)	21	1.https://communitysupportedagriculture.org.uk/what-is-csa/

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
		Total household plastic waste (based on EA 2015 spreadsheet): 287,843 tonnes % reduction: (121,012 tonnes/287,843 tonnes)*100= 42% of total household generated plastics Assuming 50% is reduced based on CSA's statement: 0.42*0.5= 0.21= 21%		
Urban farming (including aquaponic, vertical urban farming, underground farming)	Food	As people put more effort in growing the food/ participating in relevant community events/observing how food is grown on their roof, neighbourhood, community garden, they value it more, they take pride in their participation and this is likely to lead to food waste reductions A significant proportion of the food is donated to hunger relief charities etc.	-	-
Urban farming (including aquaponic, vertical urban farming)	Packaging waste (plastics)	Average person - 600kg of food with 160kg packaging Assuming 100% of plastic food packaging is	42	1.https://communitysupportedagriculture.org.uk/what-is-csa/

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
		eliminated through urban farming Manufacture of food products, beverages and tobacco products tonnes: 121,012 tonnes (according to EA 2015 spreadsheet) Total household plastic waste (based on EA 2015 spreadsheet): 287,843 tonnes % reduction: (121,012 tonnes/287,843 tonnes)*100= 42% of total household generated plastics		

A8 Laser-etched branding

The % reductions shown in yellow are the ones chosen to be used in the scenario formulation and impact assessment.

C&IW

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
Laser-etched bar coding in supermarkets	Plastic	Reduction of paper waste. 100% of the total used before. During the EU project duration (3 years): 106,660.54 m^2 Plastic in the manufacture of food products beverages and tobacco products tonnes: 121,012 tonnes per annum (taken from EA's spreadsheet from 2015)--> 121,012 tonnes*3= 363,036 tonnes 0.073 grams --> assumed weight of each sticker 22mm wide x 12mm high --> assumed area of each sticker (i.e. 0.000264 m^2) 106660,54 m2/0.000264 m2= 404,017,197 stickers 0.073*404,017,197*= 29,493,255.38 grams = 29.5 tonnes Assuming 60% of 29.5 tonnes is plastic: 17.7 tonnes Assumed only one supermarket in the UK implemented the EU project. Upscaling to all 13,889 supermarkets in the UK, but dividing by two,	34	1.https://ec.europa.eu/environment/eco-innovation/projects/en/projects/laser-mark 2.https://ec.europa.eu/environment/eco-innovation/projects/sites/eco-innovation-projects/files/projects/documents/laser_mark_project_fact_file.pdf 3.https://data.gov.uk/dataset/uk_statistics_on_waste

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
		asuuming that the EU project involved many supermarkets: 17.7 tonnes*6,944= 122,908.8 tonnes % reduction= (122,908.8 tonnes/363,036 tonnes)*100= 33.9%= 34%		
Laser-etched bar coding in supermarkets	Paper	Reduction of paper waste. 100% of the total used before. During the EU project duration (3 years): 106,660.54 m2 Paper in the manufacture of food products beverages and tobacco products tonnes: 121,012 tonnes per annum (taken from EA's spreadsheet from 2015)--> 19,681 tonnes*3= 59,043 tonnes 0.073 grams --> assumed weight of each sticker 22mm wide x 12mm high --> assumed area of each sticker (i.e. 0.000264 m2) 106,660.54 m2/0.000264 m2= 404,017,197 stickers 0.073*404,017,197*= 29,493,255.38 grams = 29.5 tonnes Assuming 20% of 29.5	69	1.https://ec.europa.eu/environment/eco-innovation/projects/sites/eco-innovation-projects/files/projects/documents/laser_mark_project_fact_file.pdf

Sector and/or process	Material	Assumptions	% reduction (average) (by weight unless stated otherwise)	Source
		tonnes is paper: 5.9 tonnes Assumed only one supermarket in the UK implemented the EU project. Upscaling to all 13,889 supermarkets in the UK, but dividing by two, asuuming that the EU project involved many supermarkets: 5.9 tonnes*6,944= 40,969 tonnes % reduction= (40,969 tonnes/59,043 tonnes)*100= 69%		

Appendix B

Assessment of CE initiatives uptake over time

B1 Additive manufacturing

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Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
1. Analysts estimated AM's overall market size to be $3.1 billion in 2013, with an annualized growth rate of 35 percent.	1. 64.3% of 507 participants in Deloitte's survey said that AM will impact their business a lot within the next 5 years 2. As the general maturity of additive manufacturing increases, the applicability of both a technological as an economical perspective increases as well.	1. Increased regulation (Controversial applications of AM have increased the regulatory scrutiny of AM-created products; observers most commonly cite the manufacturing of firearms) 2. Technology shortcomings (Currently the printable materials available are fairly limiting; manufacturers need a broader set of materials that provide better performance) 3. Cost-competitiveness (In many instances, especially for large items, traditional manufacturing techniques are more cost-competitive) 4. Talent shortage (With AM's popularity rising, the labour force demand is rapidly outpacing the supply of talent with relevant skill sets) 5. Production speed 6. Intellectual property concerns	Intermediate	1. https://www.nottingham.ac.uk/research/groups/advanced-manufacturing-technology-research-group/documents/phil.pdf 2. https://dupress.deloitte.com/dup-us-en/deloitte-review/issue-17/future-of-additive-manufacturing-industry-speaks.html 3. https://www.pwc.nl/en/assets/documents/pwc-turning-additive-manufacturing-into-business.pdf

B2 Modularity

CDEW

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement	Source
1. Popularity of modular design is on a constant rise due to benefits such as faster return on investment, better cost saving, it is an environmentally friendly construction process, flexibility and improved reputation (Building materials and techniques have improved as technology progresses) 2. Modular construction is most commonly associated with cellular type buildings such as student residences or key worker accommodation	1. It is estimated that within five years, more than 50 per cent of all construction projects will use modular construction and 3D printing (starting from 2017)	1. Potential issues with the shipping of the modules 2. Installation methods - Project size, scope, site conditions, and schedule requirements will be deciding factors on how the buildings can be ultimately assembled and erected	Minimal	1. https://www.constructionnews.co.uk/analysis/expert-opinion/modular-construction-cast-in-leading-2017-role/10015841.article 2. http://www.cityam.com/253113/construction-begins-europes-tallest-modular-residential 3. https://www.washingtonpost.com/realestate/modular-construction-is-an-increasingly-popular-way-to-grow/2016/03/16/5cab7fbc-ae4e-11e5-b711-1998289ffcea_story.html?utm_term=.3c8fb486be47 4. http://www.premierguarantee.co.uk/blog/industry-news/5-reasons-modular-construction-is-increasing-in-popularity/ 5. http://www.steelconstruction.info/Modular_construction#Key_technical_issues 6. https://www.constructionnews.co.uk/analysis/expert-opinion/modular-construction-cast-in-leading-2017-role/10015841.article

B3 Leased assets

CDEW

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
Façade leasing 1. A pilot project is underway at TU Delft, The Netherlands	**Façade leasing** 1. Can complement the overall development of circular design in buildings 2. Uptake can be facilitated by the achievement of higher value products, as suppliers who will retain the ownership of their products have a significant incentive to extract maximum value from them as they reach the end of their service life	1.Facade leasing is still at a novel stage, with pilot studies being carried out by TU Delft, Netherlands 2.Still in need of understanding the potential issues of the proposed business model	Intermediate-High	1. https://www.tudelft.nl/en/architecture-and-the-built-environment/research/projects/green-building-innovation/facade-leasing/facade-leasing-pilot-project-at-tu-delft/

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Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
General 1. In 2003, the UK accounted for 17% of total European leasing activity **Chemical leasing** 1. The chemical leasing concept has been moving beyond the trial stage	-	**Selling resource management instead of waste disposal in manufacturing** 1. Businesses should be willing to move away from the traditional business model of recruiting a waste and recycling contractor	Intermediate	1. http://www.fleetnews.co.uk/news/fleet-industry-news/2017/02/07/unstable-political-climate-increases-uptake-in-leasing-1 2. https://www.hw.ac.uk/schools/soc

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
and is being offered as a genuine commercial option. 2. The COMPLEASE™ solution was recently awarded a gold award in the category for "Case Studies" at the Global Chemical Leasing Awards in 2012, highlighting three successful customers in the UK, Germany and Serbia		2. Business should understand the benefits of investing in hiring a resource manager **Battery leasing** 1. A significant number of electric car buyers are not content with using a leased batter and they would rather buy it, due to higher running costs 2. Annual mileage is restricted for electric vehicles with elased batteries 3. Customers are tied in a relatively long-term contract (e.g. 3 years) **Chemical leasing** 1. This method does not help remove hazardous substances, so there is not necessarily a great incentive for green chemistry, and this may stifle the move to safer alternatives 2. Chemical leasing is only applicable to non-reactant chemicals that are indirectly used in processes, i.e. not ending up as part of the final product 3. It may involve employing additional staff that must become familiar with the processes of the chemical user (as the product is provided as a service)		ial-sciences/documents/dp2004-af04.pdf 3. https://app.croneri.co.uk/feature-articles/chemical-leasing-business-model-sustainable-chemicals-management 4. http://pushevs.com/2016/05/18/renault-finally-admits-the-problem-with-mandatory-battery-lease/

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
		4. To become a service provider, the chemical supplier has to change the nature of its core business (the production of chemicals), which might be a barrier to change. This could pose a problem if the chemical supplier is a small company with limited resources 5. The price for the service needs to include the costs to the service provider: These costs should include: nonmaterial costs (e.g. utilities, labour, waste treatment, inbound and outbound logistics, overheads, and insurance), environmental and social costs and profit generation for the service provider		

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Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
Clothes renting 1. Clothes renting applications are seen as environmentally friendly, especially by the younger age groups	-	**Selling resource management instead of waste disposal in manufacturing** 1. Businesses should be willing to move away from the traditional business model of recruiting a waste and recycling contractor	Intermediate	1. http://www.leasetelecom.com/are-contract-deals-for-phones-over-in-the-uk/ 2. https://www.ellenmacarthurfoundation.org/circular-

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
2. A lot of people can't afford the timeless brands new but they still appreciate the quality 3. Yerdle (a clothes renting mobile application) had more than 300,000 members in 2015, and is growing 30 percent month over month **Mobile phones leasing** 1. Leasing plans, where the buyer never owns the piece and can return it for an upgrade after a certain period have become more prevalent since early 2016 **Washing machine leasing** 1. Home appliance manufacturers such as Bosch Siemens Hausgeräte provide leasing to customers under a 'full service' scheme, which includes warranties that cover the whole contract time frame 2. Existing models have illustrated potential for increasing material productivity		2. Business should understand the benefits of investing in hiring a resource manager **Battery leasing** 1. A significant number of electric car buyers are not content with using a leased batter and they would rather buy it, due to higher running costs 2. Annual mileage is restricted for electric vehicles with leased batteries 3. Customers are tied in a relatively long-term contract (e.g. 3 years) **Chemical leasing** 1. This method does not help remove hazardous substances, so there is not necessarily a great incentive for green chemistry, and this may stifle the move to safer alternatives 2. Chemical leasing is only applicable to non-reactant chemicals that are indirectly used in processes, i.e. not ending up as part of the final product 3. It may involve employing additional staff that must become familiar with the processes of the chemical user (as the product is provided as a service)		economy/interactive-diagram/in-depth-washing-machines 3. https://www.ellenmacarthurfoundation.org/news/but-does-it-actually-work

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
		4. To become a service provider, the chemical supplier has to change the nature of its core business (the production of chemicals), which might be a barrier to change. This could pose a problem if the chemical supplier is a small company with limited resources 5. The price for the service needs to include the costs to the service provider: These costs should include: nonmaterial costs (e.g. utilities, labour, waste treatment, inbound and outbound logistics, overheads, and insurance), environmental and social costs and profit generation for the service provider		

B4 Smart predictive maintenance

C&IW

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
Improved inventory management 1. There is a growing number of inventory management software, making them more competitive and	-	**General** 1. In many businesses the volume of data is too big or it moves too fast or it	Intermediate	1. https://financesonline.com/top-15-inventory-management-solutions/

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
inducing them to improve their service offering		exceeds the current processing capacity of current technology applications 2. In certain cases it relies on the provision of good data/complete datasets from suppliers (of products that need to be properly traced) **Computerised maintenance management system (CMMS)** 1. Improper selection of CMMS vendor 2. Lack of commitment to properly implement the CMMS 3. Lack of commitment to persist in CMMS use and integration (While CMMS provides significant advantages, they need to be maintained)		

B5 Urban analytics

CDEW

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
Lean construction 1. High Lean intensity projects were three times more likely to complete ahead of schedule and two times more likely to complete under budget 2. Lean thinking in construction is not a new concept and has been explored since the 1990's **BIM** 1. The UK has proposed a mandate for implementing level 2 BIM on all government projects by 2016 2. The amount of benefits in terms of higher productivity, better efficiency, improved project control via collaboration and the cost and time efficiencies, that BIM provides, has placed it, at the heart of the construction sector in UK	-	**Lean construction** 1. Fragmentation and sub-contracting in construction means that there is little incentive for project teams to learn together 2. Key stakeholders need to be engaged early and should continue to be engaged throughout the project to ensure the success of lean methods 3. Many people object on first exposure because lean thinking appears to be the application of a manufacturing technique to construction	Minimal-Intermediate	1. https://www.leanconstruction.org/media/library/id39/Why_Isn%E2%80%99t_The_UK_Construction_Industry_Going_Lean_With_Gusto.pdf 2. https://www.leanconstruction.org/press-release/lean-projects-three-times-likely-complete-ahead-schedule-according-dodge-data-analytics-research/ 3. http://www.mckinsey.com/business-functions/operations/our-insights/when-big-data-goes-lean 4. https://www.leanconstruction.org/media/library/id13/Implementing_Lean_Construction_Understanding_and_Action.pdf 5. http://www.architectureanddesign.com.au/features/features-articles/worldwide-adoption-of-bim-popularity-in-uk-middle

C&IW

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
General 1. Pioneers in the application of advanced-analytics approaches, some borrowed from risk management and finance, are emerging in industries such as chemicals, electronics, pharmaceuticals, and consumer products. **Office/commercial waste tracking services** 1. There are numerous waste tracking services both in the UK and abroad, many of which are gaining popularity due to their ease of use, allowing real-time collaborations between stakeholders	-	1. With terabytes and petabytes of data entering the systems of organisations today, traditional architectures and infrastructures are not up to the challenge 2. IT teams are burdened with ever-growing requests for data, ad hoc analyses and one-off reports 3. It is sometimes difficult for companies to find the right use of big data analytics (i.e. without having a well-developed, right business use case 4. Getting the technology right - Many companies are not aware of the possibilities available to help them improve their analysis (e.g. that they should make good use of visual analytics) 5. The right talent, resources and skills are many times difficult to be found 6. The available data quality is often poor	Intermediate	1. http://www.zerowastescotland.org.uk/content/next-big-thing-big-data-and-circular-economy 2. https://www.bigbrotherwatch.org.uk/liftingthelid.pdf 3. http://www.capterra.com/waste-management-software/ 4. https://www.linkedin.com/pulse/7-implementation-challenges-big-data-analytics-laurent-fayet

HW

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
Meal planning 1. The popularity of applications, such as 222 million tons, is not very high, due to the bad reviews received, due to issues such as the provision of lengthy shopping lists, which may result in waste for smaller families, while they also assume the recipes will be cooked in order throughout the week	-	1. Some applications (e.g. 222 million tons) are only available on certain digital platforms (e.g. iPad) 2. Many meal planning applications (and other similar phone applications) are not updated regularly, making the user experience quite negative	High	1.http://www.foodandnutrition.org/March-April-2014/222-Million-Tons-11/ 2.http://lifehacker.com/five-best-meal-planning-apps-1533809184

B6 Exchange platforms

CDEW

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
1. Enviromate has already helped over twenty projects across the UK along with over 10,000 users already buying and selling material on the marketplace itself 2. Recipro has been operating in Greater London (among other locations) since 2008 and has collaborated in major projects, demonstrating successful business	-	1. Education/awareness of businesses 2. Perceived or actual quality of exchanged materials	Intermediate	1. http://magazine.startus.cc/enviromate-stands-for-change/ 2. http://www.travisperkinsplc.co.uk/news-and-media/our-stories/recipro-partnership.aspx 3. http://thescipub.com/PDF/ajessp.2013.14.24.pdf

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
cases (e.g. collaboration with Travis Perkins)				

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Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
General office waste (paper, plastics, cardboard) 1. The Smile survey found that goods that have been exchanged to date include: plastic reels; CD cases; plastic containers; fabric; bags; pallets; Styrofoam packaging; surplus goods; cardboard boxes; print; ; shredded paper; foam pieces; 15,000 unusable hotel key cards; photocopier; pallets; metal steps; pallet stacker; office tables; ceramic beads; abrasive belts; desktop PC; paper' furniture; latex gloves; string; wood pallets; uniforms **Food exchange** 1. The Smile survey, completed by over 100 businesses throughout Munster, indicates that SMEs are actively engaging in actions to reduce their environmental impact, with the majority of companies (92%) disposing of unwanted waste	-	1. The Smile survey indicates that 48% also still sending quantities of waste to landfill	Intermediate - High	1. https://www.justpark.com/creative/sharing-economy-index/ 2. https://www.justpark.com/creative/sharing-economy-index/ 3. http://aisel.aisnet.org/cgi/viewcontent.cgi?article=1369&context=bise 4. http://forms.360dublincity.com/152230/SMILEPressRelease_DublinLaunch_AnTaoiseach_Sept12.pdf

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
through recycling				

HW

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
Clothes exchange 1. There are already numerous clothes exchange applications, both in the UK and abroad (some of them, like Vinted, already have 12 million members, with an average of 90 items being sold/exchanged every minute **Tools library** 1. The inventory of the Toronto library began to grow soon after its establishment, as the assumption that there were too many unused tools already was proved correct. 2. Various media attention followed, which stimulated	**Tools library** 1. A more successful future could lie in making the tools lending service a municipal utility, and the route to that goal could be via public libraries.	**Clothes exchange applications** 1. Lack of trust between users 2. Many users misuse (or take advantage) of the service 3. Start-ups (e.g. Threadflip in San Francisco), failed even after having 1.5 million members, one of the main reasons being competition from similar sites **Tools library** 1. The tool library movement is alive and well, but this is about infrastructure; bricks and mortar. It's being driven by local, physical hubs as opposed to the similar online peer-to-peer platforms that offered so much early promise. As a result it is not cheap, and does not scale with the same astonishing pace of an AirBnB or Uber. 2. Toronto Tool Library is a non-profit, with no investors, and is	Intermediate - High	1. https://www.justpark.com/creative/sharing-economy-index/ 2. https://www.justpark.com/creative/sharing-economy-index/ 3. http://aisel.aisnet.org/cgi/viewcontent.cgi?article=1369&context=bise 4. https://techcrunch.com/2016/01/12/rip-threadflip/ 5. https://www.ellenmacarthurfoundation.org/case-studies/how-tool-sharing-could-become-a-public-utility 6. http://www.shareable.net/blog/5-

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
further donations (Toronto Tools Library) 3. Surprisingly, it was not some cash incentive or discount that led to tools donations, but instead the prospect of clearing space in the home, getting rid of a device that had been replaced or upgraded, or simply due to an admiration of the Tool Library vision.		reliant on finite grants and membership to keep the lights on.		free-apps-to-swap-share-and-sell-your-extra-stuff 7. https://www.vinted.co.uk/about

B7 Sharing platforms

C&IW

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
Food sharing 1. Businesses can easily give out for free, their unsold food which could end up in the bin by using applications like OLIO	-	**Food sharing** 1. So far, mostly small, independent places have started using Too Good To Go in London 2. Unlike conventional food delivery applications, customers	High	1. https://www.justpark.com/creative/sharing-economy-index/ 2. https://www.justpark.com/creative/sharing-economy-index/

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
2. At the same time, by using food sharing applications, businesses have been attracting new customers 3. Applications like Too Good To Go, have already taken off in Denmark 4. Applications like Too Good To Go have already received positive reviews due to the good cause, and an original idea on how to tackle food waste		are given a large time window (of two-three hours or more) of when to pick up their food, and a menu is not provided, as availability is subject to what remains available after the end of the day 3. Met with controversy, unless such food sharing applications, can partner up with charities, or find other means by which to feed the homeless and other people in need		3. https://www.pwc.com/us/en/technology/publications/assets/pwc-consumer-intelligence-series-the-sharing-economy.pdf 4. https://www.linkedin.com/pulse/building-uk-success-olio-now-available-33-more-saasha-celestial-one 5. http://lcrn.org.uk/olio-the-food-sharing-revolution/ 6. http://www.crowdfunder.co.uk/too-good-to-go

HW

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
General 1. 44% of US consumers are familiar with the sharing economy 2. Mostly popular with 18-24 year olds **Clothes sharing** 1. Sharing with peers who are themselves fashion-conscious,	-	1. People have stated that the sharing economy experience is not consistent 2. Some people may not trust sharing economy companies until they are recommended by someone they trust 3. Ownership often equates	High	1. https://www.theguardian.com/fashion/costume-and-culture/2014/feb/21/would-you-share-wardrobe-clothes-rentez-vouz 2. https://www.justpark.com/creative/sharing-economy-index/

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
offers opportunities for social engagement. **Food sharing** 1. OLIO achieved 50,000 downloads across the UK in its first six months 2. OLIO is already being used across London, with		to "possessiveness and attachment", making an object feel like "a part of our extended self", and these emotions tend to discourage sharing. 4. Some sectors of the fashion industry are driven by the desire for exclusivity. We purchase branded fashions rather than mass-market alternatives partly because of the guarantee that these garments are more exclusive. Exclusivity is compromised by sharing. 5. Regulatory uncertainty		3. https://www.justpark.com/creative/sharing-economy-index/ 4. https://www.pwc.com/us/en/technology/publications/assets/pwc-consumer-intelligence-series-the-sharing-economy.pdf 5. http://www.economist.com/news/leaders/21573104-internet-everything-hire-rise-sharing-economy

B8 Urban farming

HW

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
1. Large-scale urban agriculture is on the rise	1. A huge part of the urban farming movement in the	1. One of the biggest challenges going forward	Minimal - Intermediate	1. https://www.forbes.com/sites/laurieewinkless/2016/03/09/urban-

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
globally, with more and more farms appearing in our cities. 2. Investment is opening up in the UK, with several urban farms planned across the country over the next few years – from Greater Manchester to London, and beyond (2016)	city has been the reclamation of underutilized or abandoned spaces	will be growing other crops like rice and wheat, crops that could feed the world 2. Large urban farms are so far afield from traditional ones that "farm" may not be the word for them 3. Difficult to find enough space to grow enough food items to feed a household significantly 4. Although rooftops appear to be an option, they are often covered with ducting, skylights, and vents, which makes all your 'farm plots' small and broken up. Also, rooftops are not often designed for the heavy load.		farming-fad-or-futureproof/#66d94c08472b 2. http://theconversation.com/urban-farms-wont-feed-our-cities-but-theyre-still-a-great-idea-heres-why-66107 3. https://www.theguardian.com/environment/2016/aug/14/world-largest-vertical-farm-newark-green-revolution

B9 Laser-etched branding

C&IW

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
1. The concept of laser printing labels took off in 2013, when Laser Food, a Spanish company specializing in laser marking agro alimentary products, teamed up with researchers at the University of Valencia to develop a tool that could reliably and legibly mark fruits and vegetables without affecting their quality 2. While the natural branding technique has been used in other European markets, ICA's involvement is the largest trial to date. 3. Large pilot study only currently in Sweden (Swedish grocery chain ICA and the Dutch fruit and vegetable supplier Nature & More have teamed up to replace produce stickers with laser-printed labels) 4. ICA's pilot program is already receiving positive reception, leading the	-	1. Laser marking can't be used on all produce. Citrus fruit, for example, has the ability to heal itself, meaning the etchings would disappear after just a few hours 2. Leafy greens are about the only produce the system doesn't work well on	Minimal-Intermediate	1. http://www.fooddive.com/news/grocery--will-laser-marking-replace-produce-stickers/434185/ 2. http://www.sustainablebrands.com/news_and_views/products_design/libby_maccarthy/trending_food_industry_aims_cut_waste_two_new_food_la 3. http://www.thepacker.com/fruit-vegetable-news/laser_labeling_system_tattoos_fruits_vegetables_122123859.html

Current uptake	Future projected uptake	Main barriers to implementation	Level of business/public engagement required to facilitate uptake	Source
supermarket chain to consider expansion into other products 5. The method has no impact on the product's quality or shelf life.				

Appendix C

Scenario formulation assumptions

C1 Low uptake scenario

CDEW

CE initiative	Main barriers to implementation	Fraction of high uptake scenario (max 25%)
Additive manufacturing	1. Increased regulation (Controversial applications of AM have increased the regulatory scrutiny of AM-created products; observers most commonly cite the manufacturing of firearms) 2. Technology shortcomings (Currently the printable materials available are fairly limiting; manufacturers need a broader set of materials that provide better performance) 3. Cost-competitiveness (In many instances, especially for large items, traditional manufacturing techniques are more cost-competitive) 4. Talent shortage (With AM's popularity rising, the labour force demand is rapidly outpacing the supply of talent with relevant skill sets) 5. Production speed 6. Intellectual property concerns	20%
Modularity	1. Potential issues with the shipping of the modules 2. Installation methods - Project size, scope, site conditions, and schedule requirements will be deciding factors on how the buildings can be ultimately assembled and erected	25%
Leased assets	1.Facade leasing is still at a novel stage, with pilot studies being carried out by TU Delft, Netherlands 2.Still in need of understanding the potential issues of the proposed business model	20%
Urban analytics	**Lean construction** 1. Fragmentation and sub-contracting in construction means that there is little incentive for project teams to learn together 2. Key stakeholders need to be engaged early and should continue	25%

CE initiative	Main barriers to implementation	Fraction of high uptake scenario (max 25%)
	to be engaged throughout the project to ensure the success of lean methods 3. Many people object on first exposure because lean thinking appears to be the application of a manufacturing technique to construction	
Exchange platforms	1. Education/awareness of businesses 2. Perceived or actual quality of exchanged materials	20%

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CE initiative	Main barriers to implementation	Fraction of high uptake scenario (max 25%)
Leased assets	**Battery leasing** 1. A significant number of electric car buyers are not content with using a leased battery and they would rather buy it, due to higher running costs 2. Annual mileage is restricted for electric vehicles with leased batteries 3. Customers are tied in a relatively long-term contract (e.g. 3 years) **Chemical leasing** 1. This method does not help remove hazardous substances, so there is not necessarily a great incentive for green chemistry, and this may stifle the move to safer alternatives 2. Chemical leasing is only applicable to non-reactant chemicals that are indirectly used in processes, i.e. not ending up as part of the final product 3. It may involve employing additional staff that must become familiar with the processes of the chemical user (as the product is provided as a service) 4. To become a service provider, the chemical supplier has to change the nature of its core business (the production of chemicals), which might be a barrier to change. This	25%

CE initiative	Main barriers to implementation	Fraction of high uptake scenario (max 25%)
	could pose a problem if the chemical supplier is a small company with limited resources 5. The price for the service needs to include the costs to the service provider: These costs should include: nonmaterial costs (e.g. utilities, labour, waste treatment, inbound and outbound logistics, overheads, and insurance), environmental and social costs and profit generation for the service provider **Selling resource management instead of waste disposal in manufacturing** 1. Businesses should be willing to move away from the traditional business model of recruiting a waste and recycling contractor 2. Business should understand the benefits of investing in hiring a resource manager	
Smart predictive maintenance	1. In many businesses the volume of data is too big or it moves too fast or it exceeds the current processing capacity of current technology applications 2. In certain cases it relies on the provision of good data/complete datasets from suppliers (of products that need to be properly traced) **CMMS** 1. Improper selection of CMMS vendor 2. Lack of commitment to properly implement the CMMS 3. Lack of commitment to persist in CMMS use and integration (While CMMS provides significant advantages, they need to be maintained)	25%
Urban analytics	1. With terabytes and petabytes of data entering the systems of organisations today, traditional architectures and infrastructures are not up to the challenge 2. IT teams are burdened with ever-growing requests for data, ad hoc	25%

CE initiative	Main barriers to implementation	Fraction of high uptake scenario (max 25%)
	analyses and one-off reports 3. It is sometimes difficult for companies to find the right use of big data analytics (i.e. without having a well-developed, right business use case 4. Getting the technology right - Many companies are not aware of the possibilities available to help them improve their analysis (e.g. that they should make good use of visual analytics) 5. The right talent, resources and skills are many times difficult to be found 6. The available data quality is often poor	
Exchange platforms	**Food exchange** 1. The Smile survey, completed by over 100 businesses throughout Munster, indicates that SMEs are actively engaging in actions to reduce their environmental impact, with the majority of companies (92%) disposing of unwanted waste through recycling; although 48% also still sending quantities of waste to landfill	20%
Sharing platforms	**Food sharing** 1. So far, mostly small, independent places have started using surplus food selling applications, such as Too Good To Go in London 2. Unlike conventional food delivery applications, customers are given a large time window (of two-three hours or more) of when to pick up their food, and a menu is not provided, as availability is subject to what remains available after the end of the day 3. Met with controversy, unless such food sharing applications, can partner up with charities, or find other means by which to feed the homeless and other people in need	15%
Laser-etched branding	1. Laser marking can't be used on all produce. Citrus fruit, for example, has the ability to heal itself, meaning the etchings would	25%

CE initiative	Main barriers to implementation	Fraction of high uptake scenario (max 25%)
	disappear after just a few hours 2. Leafy greens cannot be laser-etched	

HW

CE initiative	Main barriers to implementation	Fraction of high uptake scenario (max 25%)
Leased assets	**Clothes leasing** 1. Opposition from luxury brands who see their clothes as being publicly promoted and worn by the 'wrong' people (i.e. not their target group) according to their beliefs (e.g. everyday people posting photos in luxury brand dresses on clothes rental sites) 2. People may find it hard to move away from their current clothes-purchasing habits 3. Unless the leasing involves luxury brands that people cannot afford, people are more likely to buy their clothes, as this gives them a sense of ownership that they are used to having and are likely to want to continue enjoying **Washing machine leasing** 1. Customers will not accept new, alternative contract schemes 2. In a leasing scheme, the producer faces a maturity mismatch between upfront production costs and future cash flow streams. Financing this gap from the company's own funds could be a financing risk to a certain extent 3. The end of Electrolux's experiment with its new leasing business model shows that challenges may arise in the cooperation with business partners	25%
Urban analytics	1. Some applications (e.g. 222 million tons) are only available on certain digital platforms (e.g. iPad) 2. Many meal planning applications (and other similar phone applications) are not updated	15%

CE initiative	Main barriers to implementation	Fraction of high uptake scenario (max 25%)
	regularly, making the user experience quite negative	
Exchange platforms	**Clothes exchange** 1. Lack of trust between users 2. Many users misuse (or take advantage) of the service 3. Start-ups (e.g. Threadflip in San Francisco), failed even after having 1.5 million members, one of the main reasons being competition from similar sites **Tools library** 1. The tool library movement is alive and well, but this is about infrastructure; bricks and mortar. It's being driven by local, physical hubs as opposed to the similar online peer-to-peer platforms that offered so much early promise. As a result it is not cheap, and does not scale with the same astonishing pace of an AirBnB or Uber 2. Toronto Tool Library is a non-profit, with no investors, and is reliant on finite grants and membership to keep the lights on	10%
Sharing platforms	1. People have stated that the sharing economy experience is not consistent 2. Some people may not trust sharing economy companies until they are recommended by someone they trust 3. Ownership often equates to "possessiveness and attachment", making an object feel like "a part of our extended self", and these emotions tend to discourage sharing. 4. Some sectors of the fashion industry are driven by the desire for exclusivity. People may purchase branded fashions rather than mass-market alternatives partly because of the guarantee that these garments are more exclusive. Exclusivity is compromised by sharing 5. Regulatory uncertainty	10%

CE initiative	Main barriers to implementation	Fraction of high uptake scenario (max 25%)
Urban farming	1. One of the biggest challenges going forward will be growing other crops like rice and wheat, crops that could feed the world 2. Large urban farms are so far afield from traditional ones that "farm" may not be the word for them 3. Difficult to find enough space to grow enough food items to feed a household significantly 4. Although rooftops appear to be an option, they are often covered with ducting, skylights, and vents, which makes all your "farm plots" small and broken up. Also, rooftops are not often designed for the heavy load	10%

C2 Medium uptake scenario

CDEW

CE initiative	Main barriers to implementation	Fraction of high uptake scenario (max 50%)
Additive manufacturing	1. Increased regulation (Controversial applications of AM have increased the regulatory scrutiny of AM-created products; observers most commonly cite the manufacturing of firearms) 2. Technology shortcomings (Currently the printable materials available are fairly limiting; manufacturers need a broader set of materials that provide better performance) 3. Cost-competitiveness (In many instances, especially for large items, traditional manufacturing techniques are more cost-competitive) 4. Talent shortage (With AM's popularity rising, the labour force demand is rapidly outpacing the supply of talent with relevant skill sets) 5. Production speed 6. Intellectual property concerns	40%
Modularity	1. Potential issues with the shipping of the modules 2. Installation methods - Project size, scope, site conditions, and schedule requirements will be deciding factors on how the buildings can be ultimately assembled and erected	50%
Leased assets	1.Facade leasing is still at a novel stage, with pilot studies being carried out by TU Delft, Netherlands 2.Still in need of understanding the potential issues of the proposed business model	40%
Urban analytics	**Lean construction** 1. Fragmentation and sub-contracting in construction means that there is little incentive for project teams to learn together 2. Key stakeholders need to be engaged early and should continue	50%

CE initiative	Main barriers to implementation	Fraction of high uptake scenario (max 50%)
	to be engaged throughout the project to ensure the success of lean methods 3. Many people object on first exposure because lean thinking appears to be the application of a manufacturing technique to construction	
Exchange platforms	1. Education/awareness of businesses 2. Perceived or actual quality of exchanged materials	40%

C&IW

CE initiative	Main barriers to implementation	Fraction of high uptake scenario (max 50%)
Leased assets	**Battery leasing** 1. A significant number of electric car buyers are not content with using a leased battery and they would rather buy it, due to higher running costs 2. Annual mileage is restricted for electric vehicles with leased batteries 3. Customers are tied in a relatively long-term contract (e.g. three years) **Chemical leasing** 1. This method does not help remove hazardous substances, so there is not necessarily a great incentive for green chemistry, and this may stifle the move to safer alternatives 2. Chemical leasing is only applicable to non-reactant chemicals that are indirectly used in processes, i.e. not ending up as part of the final product 3. It may involve employing additional staff that must become familiar with the processes of the chemical user (as the product is provided as a service) 4. To become a service provider, the chemical supplier has to change the nature of its core business (the production of chemicals), which might be a barrier to change. This	50%

CE initiative	Main barriers to implementation	Fraction of high uptake scenario (max 50%)
	could pose a problem if the chemical supplier is a small company with limited resources. 5. The price for the service needs to include the costs to the service provider: These costs should include: nonmaterial costs (e.g. utilities, labour, waste treatment, inbound and outbound logistics, overheads, and insurance), environmental and social costs and profit generation for the service provider **Selling resource management instead of waste disposal in manufacturing** 1. Businesses should be willing to move away from the traditional business model of recruiting a waste and recycling contractor 2. Business should understand the benefits of investing in hiring a resource manager	
Smart predictive maintenance	1. In many businesses the volume of data is too big or it moves too fast or it exceeds the current processing capacity of current technology applications 2. In certain cases it relies on the provision of good data/complete datasets from suppliers (of products that need to be properly traced) **CMMS** 1. Improper selection of CMMS vendor 2. Lack of commitment to properly implement the CMMS 3. Lack of commitment to persist in CMMS use and integration (While CMMS provides significant advantages, they need to be maintained)	50%
Urban analytics	1. With terabytes and petabytes of data entering the systems of organisations today, traditional architectures and infrastructures are not up to the challenge 2. IT teams are burdened with ever-growing requests for data, ad hoc	50%

CE initiative	Main barriers to implementation	Fraction of high uptake scenario (max 50%)
	analyses and one-off reports 3. It is sometimes difficult for companies to find the right use of big data analytics (i.e. without having a well-developed, right business use case 4. Getting the technology right - Many companies are not aware of the possibilities available to help them improve their analysis (e.g. that they should make good use of visual analytics) 5. The right talent, resources and skills are many times difficult to be found 6. The available data quality is often poor	
Sharing platforms	**Food sharing** 1. So far, mostly small, independent places have started using Too Good To Go in London 2. Unlike conventional food delivery applications, customers are given a large time window (of two-three hours or more) of when to pick up their food, and a menu is not provided, as availability is subject to what remains available after the end of the day 3. Met with controversy, unless such food sharing applications, can partner up with charities, or find other means by which to feed the homeless and other people in need	30%
Exchange platforms	1. The Smile survey, completed by over 100 businesses throughout Munster, indicates that SMEs are actively engaging in actions to reduce their environmental impact, with the majority of companies (92%) disposing of unwanted waste through recycling; although 48% also still sending quantities of waste to landfill	40%
Laser-etched branding	1. Laser marking can't be used on all produce. Citrus fruit, for example, has the ability to heal itself, meaning the etchings would disappear after just a few hours 2. Leafy greens are about the only produce the system doesn't work well on	50%

HW

CE initiative	Main barriers to implementation	Fraction of high uptake scenario (max 50%)
Leased assets	**Clothes leasing** 1. Opposition from luxury brands who see their clothes as being publicly promoted and worn by the 'wrong' people (i.e. not their target group) according to their beliefs (e.g. everyday people posting photos in luxury brand dresses on clothes rental sites) 2. Unless the leasing involves luxury brands that people cannot afford, people are more likely to buy their clothes, as this gives them a sense of ownership that they are used to having and are likely to want to continue enjoying **Washing machine leasing** 1. In a leasing scheme, the producer faces a maturity mismatch between upfront production costs and future cash flow streams. Financing this gap from the company's own funds could be a financing risk to a certain extent 2. The end of Electrolux's experiment with its new leasing business model shows that challenges may arise in the cooperation with business partners	50%
Urban analytics	1. Some applications (e.g. 222 million tons) are only available on certain digital platforms (e.g. iPad) 2. Many meal planning applications (and other similar phone applications) are not updated regularly, making the user experience quite negative	30%
Exchange platforms	**Clothes exchange** 1. Lack of trust between users 2. Many users misuse (or take advantage) of the service 3. Start-ups (e.g. Threadflip in San Francisco), failed even after having 1.5 million members, one of the main reasons being competition from similar sites	20%

CE initiative	Main barriers to implementation	Fraction of high uptake scenario (max 50%)
	Tools library 1. The tool library movement is alive and well, but this is about infrastructure; bricks and mortar. It's being driven by local, physical hubs as opposed to the similar online peer-to-peer platforms that offered so much early promise. As a result it is not cheap, and does not scale with the same astonishing pace of an AirBnB or Uber 2. Toronto Tool Library is a non-profit, with no investors, and is reliant on finite grants and membership to keep the lights on	
Sharing platforms	1. People have stated that the sharing economy experience is not consistent 2. Some people may not trust sharing economy companies until they are recommended by someone they trust 3. Ownership often equates to "possessiveness and attachment", making an object feel like "a part of our extended self", and these emotions tend to discourage sharing. 4. Some sectors of the fashion industry are driven by the desire for exclusivity. We purchase branded fashions rather than mass-market alternatives partly because of the guarantee that these garments are more exclusive. Exclusivity is compromised by sharing. 5. Regulatory uncertainty	20%
Urban farming	1. One of the biggest challenges going forward will be growing other crops like rice and wheat, crops that could feed the world 2. Large urban farms are so far afield from traditional ones that "farm" may not be the word for them 3. Difficult to find enough space to grow enough food items to feed a household significantly 4. Although rooftops appear to be an option, they are often covered with ducting, skylights, and vents, which makes all your "farm plots"	20%

CE initiative	Main barriers to implementation	Fraction of high uptake scenario (max 50%)
	small and broken up. Also, rooftops are not often designed for the heavy load	