CIRCULAR ECONOMY EFFECTS ON WASTE GENERATION IN LONDON

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ABSTRACT
This study reports on research carried out on behalf of the London Waste and Recycling Board, to assess the potential impact that the adoption of the Circular Economy can have on the generation of three principal waste types: construction, demolition and excavation waste (CDEW), commercial and industrial waste (C&IW), and household waste (HW) in Greater London, up to the year 2041. The paper takes an evidence-based, quantitative approach, demonstrating the potential real-world impacts of the Circular Economy. It stresses the importance of moving up a level on the waste hierarchy, to focus solely on waste reduction. The study estimates the waste reduction potential of nine Circular Economy initiatives and the time required for this potential to be realised (i.e. adopted by the general population). The waste reduction potential of the chosen Circular Economy initiatives, and the time-uptake factor are used to develop three Circular Economy uptake scenarios, which are tested in a waste generation impact assessment model. The waste generation impact assessment model indicates that targeting all three principal waste types can result in a significant, cumulative waste reduction. A maximum potential waste reduction of more than 60% can be achieved, with a central estimate of approximately 30%, depending on the chosen Circular Economy uptake scenario.
Keywords: Circular Economy, waste reduction, waste projections, Greater London Authority.

1 INTRODUCTION

London currently generates around seven million tonnes of waste in homes, public buildings, and businesses, of which only 52% is recycled [1]. A linear economy of take-make-dispose is inefficient and unsustainable. The Circular Economy (CE), provides a means of retaining a resource within the economic cycle and delaying the point at which the resource is discarded and thus, becomes waste.

Applying CE initiatives that specifically aim to reduce the generation of three principal waste types: construction, demolition and excavation waste (CDEW) [2], commercial and industrial waste (C&IW) [3], and household waste (HW) [4] can free up certain waste storage, transfer and waste treatment sites. If safeguarded, these sites 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 biological cycles and technical cycles of the CE butterfly diagram (Fig. 1).

This study explores how the mainstream uptake of selected CE initiatives can bring about significant reductions in waste generation across London up to the year 2041, which is the year marking the end of the latest London Plan, which will be published by the Mayor of London in 2018. The study assessed only those CE initiatives that can achieve the first stage of the waste hierarchy, which is waste prevention (hereby referred to as waste reduction). This also includes reuse, which shall not be confused with "preparation for reuse", which is the second stage of the waste hierarchy (Fig. 2).

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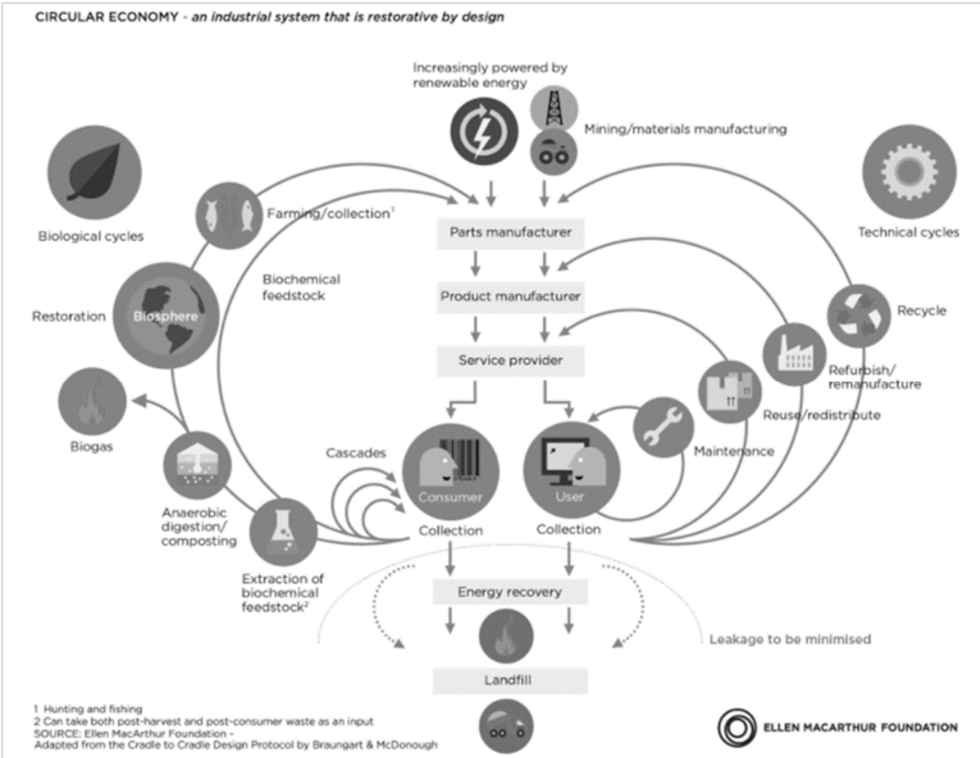

Figure 1: The CE butterfly diagram, showing the biological cycles on the left and the technical cycles on the right [5].

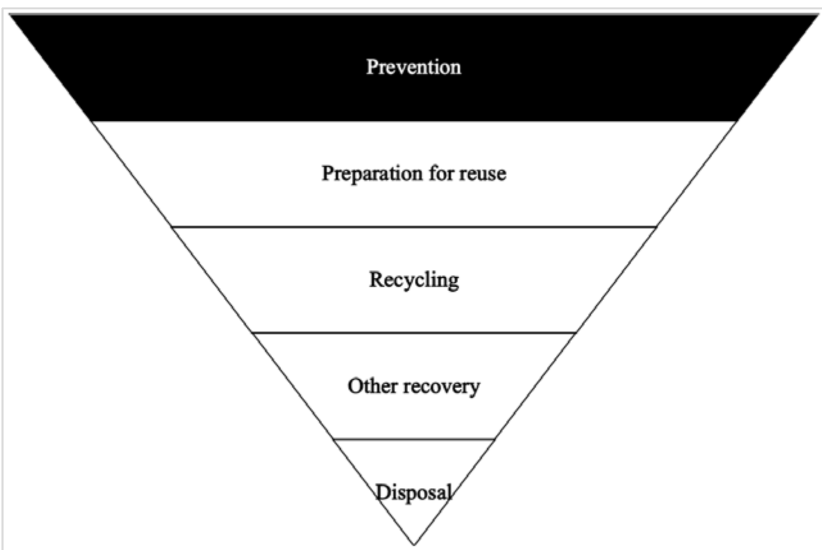

Figure 2: The waste hierarchy [6].

2 DATA COLLECTION

2.1 CE initiatives selection

Nine CE initiatives were chosen, as shown in Fig. 3. These CE initiatives target different stages of an asset's lifecycle. Modularity and laser-etched branding target the design and construction stage, leased assets, exchange platforms and sharing platforms target the procurement and operation stage, additive manufacturing targets the design and construction stage, and smart predictive maintenance and urban analytics target the operation stage. Urban farming can target different stages of an asset's lifecycle. As a result, the chosen CE initiatives can be adopted in combination, to help achieve a synergistic waste reduction, collectively targeting all three principal waste types.

A brief overview of each chosen CE initiative is provided below:

1. Additive manufacturing: Also known as 3D printing, is a technology which constructs an object layer by layer. The additive nature of the process means that less waste is created, as components can be designed to be fit for purpose [8].
2. Modularity: Designing structures in modules allows component parts to be added, removed or replaced as required. Pre-fabrication in a factory environment can reduce material wastage, compared to the traditional cast in-situ construction method, as shown by Lu and Yuan [9].

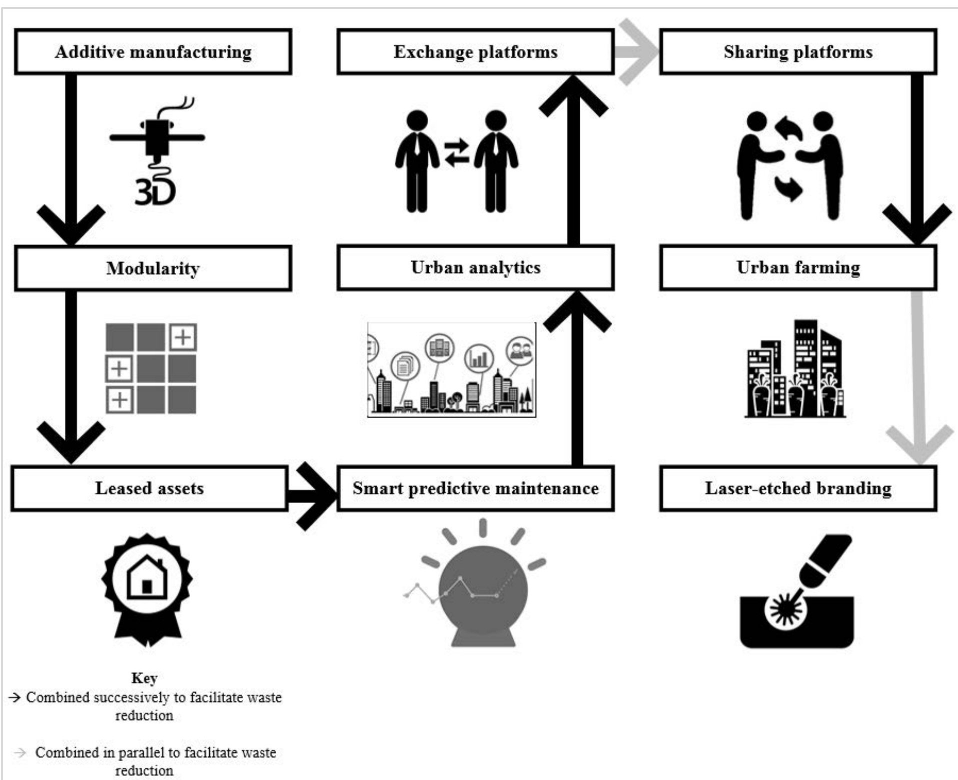

Figure 3: The selected CE initiatives [7].

3. Leased assets: In a leasing business model, the emphasis is on the “sale of use” rather than the “sale of product”. The owner of the asset retains 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 [10].
4. Smart predictive maintenance: Leasing business models can be taken one step further by including maintenance, and upgrades of the asset. Services may be monitored, repaired and upgraded remotely using smart monitoring devices that anticipate problems and carry out maintenance works; expanding the lifetime of assets [11].
5. Urban analytics: The use of real-time data processing and predictive analytics can improve resource planning. Significant amounts of real-time data can be generated from an increasing number of sources, ranging from sensor technology to crowd-sourced data [12].
6. Exchange platforms: Includes the sharing of assets, skills and services for a fee, or in exchange of another material or service. In other words, the giveaway of materials and/or services occurs on the condition of receiving something in return [13].
7. Sharing platforms: Collaborative consumption, as defined by Botsman [14] includes means by which people can share their goods and services for free, and without expecting any goods or services in return from the same person.
8. Urban farming: Includes vertical horticulture practices in industrial warehouses in urban areas. Although urban farming can tackle food waste more through preparation for reuse and recycling, as it turns large quantities of food waste into compost, citizen groups can take steps to educate the public and build awareness to help reduce packaging waste [15].
9. Laser etched branding: Grocery stores, can reduce the amount of plastic and paper used for packaging fruits and vegetables, through laser etched branding. The approach uses a laser to etch the brand onto each piece of fruit or vegetable, removing pigment from the outer layer of cells and leaving a permanent mark [16].

2.2 Waste reduction data collection

The waste reduction potential of each of the nine CE initiatives was quantified through an evidence-based numerical analysis, which involved finding data from various credible sources, as discussed in Section 5, and then making relevant assumptions, as and when necessary. The selected waste reduction percentages for each of the nine CE initiatives, are given in Table 1. Each CE initiative may apply to one, two or all three of the principal waste types. In addition, it was found that each CE initiative can be best applied to different sectors and different processes, as shown in Table 1.

2.3 Time-uptake relationship determination

A time-uptake assessment was carried out for each CE initiative, in order to estimate the period of time it would take for each CE initiative to be adopted by the population (including industries, businesses, and the general public, as applicable). The uptake is based on the technology adoption lifecycle [17]. More specifically, when the “Early Majority” (i.e. a minimum of 34% of the population) has started to actively adopt the CE initiative, this is the time when the CE initiative is considered to have “taken off”. However, as it was difficult to assess this quantitatively, a qualitative assessment was undertaken for each of the three principal waste types, for each CE initiative. Based on this qualitative assessment, each of the nine CE initiatives was given a rank from 1–9 (with one being the first CE initiative to be taken up).

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Table 1: Summary of waste reductions.

CE initiative	Type of waste	Sector and/or process	% reduction by weight
Additive manufacturing	CDEW	Construction-scale additive manufacturing	45
Modularity	CDEW	Pre-fabrication	6.5
Leased assets	CDEW	Façade leasing	16
	C&IW	Resource management instead of waste disposal in manufacturing	25
		Chemical leasing for cleaning operations	92
		Battery leasing	25
	HW	Clothes renting	30
		Washing machine leasing	14
Smart predictive maintenance	C&IW	Improved inventory management	18
Urban analytics	CDEW	Building Information Modelling (BIM)	45
	C&IW	Waste tracking and analytics applied by restaurants/food service providers	24
		Waste tracking and analytics applied in retail	35
	HW	Home meal planning mobile applications	69
Exchange platforms	CDEW	Surplus construction materials selling services	14
	C&IW	Equipment exchange services for businesses	5
		Surplus food exchange services for businesses	10
	HW	Clothes trading applications	5
		Tools libraries	12
Sharing platforms	C&IW	Surplus food sharing mobile applications used by supermarkets	10
	HW	Surplus household items sharing mobile applications	40
		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 bar coding in supermarkets (paper)	69

Table 2: 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)
Urban farming	n/a	n/a	15 years (2031)
Laser-etched branding	n/a	10 years (2026)	n/a

Ranks allocated to each CE initiative, were assumed to be fixed, regardless of whether an emphasis was given on a specific waste type within each CE initiative. The assessment was based on: current levels of uptake; projected future levels of uptake; main barriers to uptake; and the level of public engagement required to facilitate the uptake. Due to behavioural change obstacles, the uptake is, in general, slower to achieve on a household level, compared to the industrial and commercial sector.

Based on the time-uptake ranking, the period of time that is likely to be required for the full effect of the initiative to be achieved, was determined. Table 2 sets out the number of years required for each initiative and waste type, to take full effect. Time factor ("*t*") was incorporated into the waste reduction potential; for instance, as it take 15 years for additive manufacturing to fully target CDEW (see Table 2), the full value of t (i.e. t=1) was divided by three to account for the three five-year increments before the full potential could be reached (eqns (1), (2) in Section 3).

2.4 CE transition scenarios

SLR Consulting Ltd (SLR) prepared a waste projections model on behalf of the Greater London Authority (GLA) in order to inform the Further Alterations to the London Plan (FALP) publication [18]. The model (hereby referred to as "the GLA model") includes projections for CDEW, C&IW and local authority collected waste (LACW) (which is divided into HW and non-household LACW). The updated 2017 version of the GLA model was treated as the "business as usual" scenario, against which three CE uptake scenarios were tested, including:

- Low CE uptake scenario (i.e. "the conservative approach") – all CE initiatives will be implemented only to some extent; for the purposes of this study the maximum proportion was 25% (e.g. for additive manufacturing, the 45% by weight reduction in CDEW (see Table 1) would only be realised by 20% (see Table 3));
- Medium CE uptake scenario (i.e. "the realistic approach") – all CE initiatives will be implemented to the best level that is currently thought to be technologically, financially, socially and environmentally feasible; for the purposes of this study the maximum

proportion was 50% (e.g. for additive manufacturing, the 45% by weight reduction in CDEW (see Table 1) would only be realised by 40% (see Table 3)); and
- High CE uptake scenario (i.e. "the ambitious approach") – all CE initiatives will be implemented to the highest possible quantifiable uptake level (e.g. for additive manufacturing, the 45% by weight reduction in CDEW (see Table 1) would be realised by 100% (see Table 3)).

All the waste projections use baseline data and take no account of other waste reduction assumptions used for land planning purposes, i.e. the GLA's target of a 5% reduction in waste generation by 2031 compared to 2016 waste generation.

3 IMPACT ASSESSMENT

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 generation of C&IW and HW. The waste composition for both C&IW and HW was obtained from the Department for Environment, Food and Rural Affairs (Defra) [19]. For C&IW composition, only the commercial proportion was considered, due to practicality purposes.

The relevant CE initiatives for each of the three principal waste types, together with the waste reduction achieved for each waste type under each scenario, as well as the time factor "t" were applied to the GLA model (i.e. the "business as usual" scenario), for all the years between 2016 and 2041.

The overall CDEW percentage reduction for a given year under a specific CE uptake scenario was calculated as follows [7]:

$$W_y - W_y \cdot \sum_i t_{ix} \cdot ce_{sciwr}, \quad (1)$$

where W_y = GLA model waste projection for year y, ce_{sciwr} = waste reduction % for ith CE initiative under a specific scenario sc, and t_{ix} = time factor t after x years for the ith initiative.

Table 3: Percentage of uptake for the three CE uptake scenarios.

CE initiative	CDEW (low/medium/high %)	C&IW (low/medium/high %)	HW (low/medium/high %)
Additive manufacturing	20/40/100	–/–/–	–/–/–
Modularity	25/50/100	–/–/–	–/–/–
Leased assets	20/40/100	25/50/100	25/50/100
Smart predictive maintenance	–/–/–	25/50/100	–/–/–
Urban analytics	25/50/100	25/50/100	15/30/100
Exchange platforms	20/40/100	20/40/100	10/20/100
Sharing platforms	–/–/–	15/3/100	10/20/100
Urban farming	–/–/–	–/–/–	10/20/100
Laser-etched branding	–/–/–	25/50/100	–/–/–

The C&IW and HW percentage reduction for a specific waste stream for a given year under a specific CE uptake scenario was calculated as follows [7]:

$$D_y - D_y \cdot \sum_i t_{ix} \cdot ce_{sciwr}\,, \tag{2}$$

where D_y = Defra waste generation figure for year y for specific waste stream s, ce_{sciwr} = waste reduction % for ith CE initiative under a specific scenario sc, and t_{ix} = time factor t for the ith initiative after x years.

Overall C&IW or HW percentage reduction for a specific waste stream for a given year under a specific CE uptake scenario was calculated as follows [7]:

$$Wy - \left(Wd - \left(\sum DRys \cdot Wds\right)\right), \tag{3}$$

where W_y = GLA model waste projection for year y, DR_{ys} = Result of eqn (2), W_{ds} = Defra total waste generation for year y for waste stream s.

4 RESULTS

All the waste reduction percentages achieved over time (in five-year increments) under all CE uptake scenarios (Low, Med., High) and for all waste types are given in Fig. 4.

The cumulative waste generation results for the three principal waste types, can be found in Fig. 5. All the results are given in five-year increments, between 2016 and 2041.

The total percentage reductions for all three waste types achieved over the London Plan period under each CE uptake scenario are given in Fig. 6.

5 DISCUSSION

The study showed that applying CE initiatives can significantly reduce waste generation over a relatively short period of time, of less than 25 years. The magnitude and speed of reduction appeared to be higher for CDEW, regardless of the predicted level of uptake.

As the study aimed to take an evidence-based approach, there was a challenge in identifying relevant data, or in making valid estimations based on available data. In order to avoid the use of any arbitrary figures, the research was based on information taken from

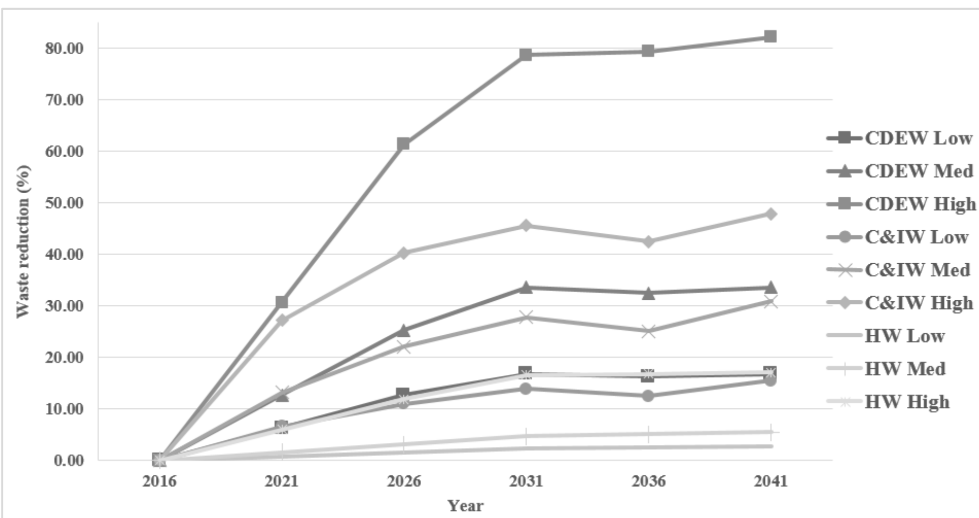

Figure 4: Waste reduction by scenario and waste type.

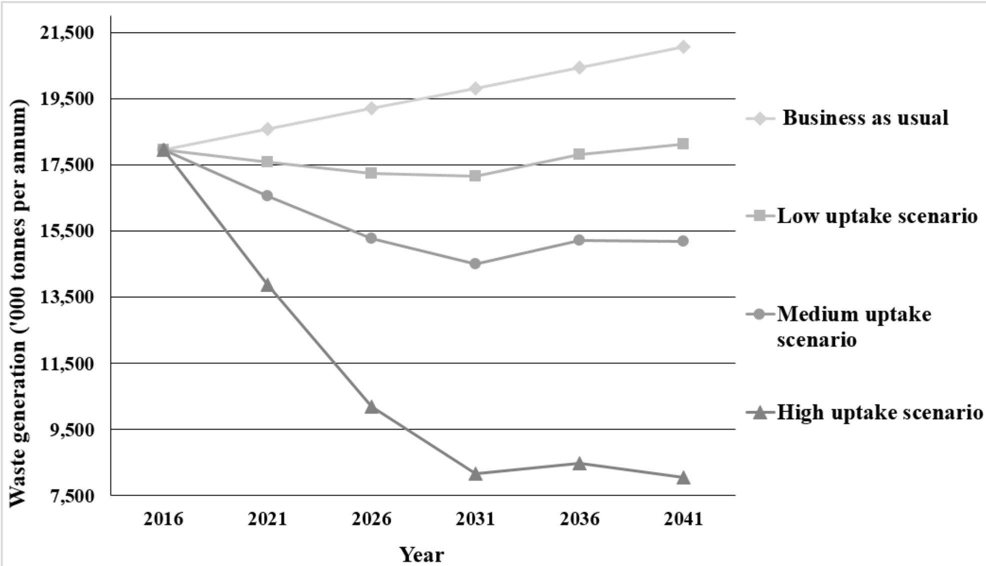

Figure 5: Total waste generation projections under the different scenarios.

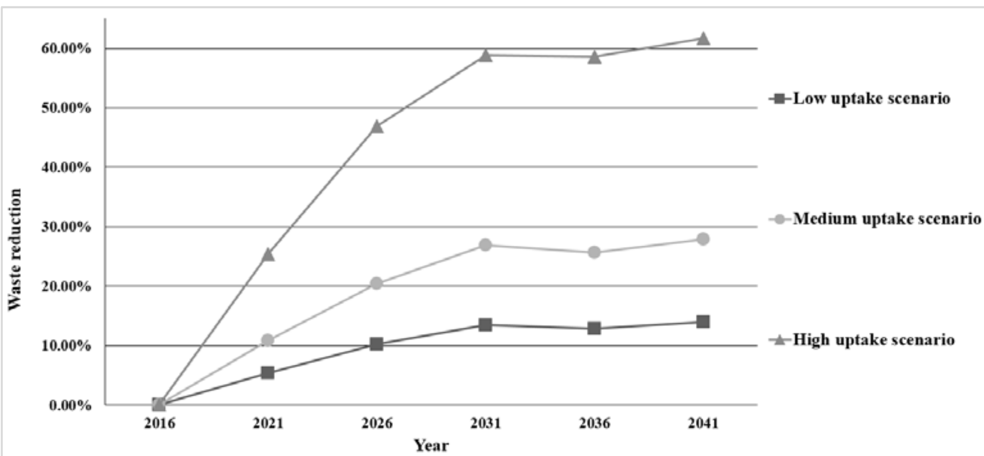

Figure 6: Total percentage waste reductions under the different scenarios.

relevant academic papers, European Commission studies, United Kingdom public bodies (e.g. Transport for London), local governments and relevant charitable organisations (e.g. the Ellen MacArthur Foundation).

The HW reduction results indicate that it will be more challenging to reduce waste generation at a household level. However, this is because the difficulty of targeting behavioural change at a household level was factored into the impact assessment. Therefore, with a well-targeted and pro-active policy-making and strategy development by local authorities and central governments, HW reduction can be accelerated.

To understand the feasibility of achieving significant waste reduction, a comparison was made to Slovenia, which is an exemplary case of a country which, only 15 years ago, had almost zero reuse, recycling and recovery rates for municipal solid waste, but has since made a rapid transition towards applying both the waste hierarchy and CE [20]. According to Snaga, who is the public utility company responsible for waste collection in the capital Ljubljana and six suburban municipalities, the key to their success has been due to political support, proactive management and a commitment to zero waste since 2014.

The evident gap between the high CE uptake scenario and the other two CE uptake scenarios (Figs 5, 6), is attributed to the maximum uptake assigned to each scenario (i.e. 25% for low uptake scenario, 50% for medium uptake scenario and 100% for high uptake scenario). However, the high CE uptake scenario can clearly demonstrate the fully realised potential, which was the aim of this study. This highlights the need for implementing appropriate measures to speed up the transition to a CE, so that the full potential can be realised.

6 CONCLUSION

The results indicate that targeting all three principal waste types can achieve a significant, cumulative waste reduction over a period of 25 years. The results also support that a maximum potential waste reduction of more than 60% can be achieved, with a central estimate of approximately 30% waste reduction, depending on the chosen CE uptake scenario.

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