European Journal of Sustainable Development (2026), **15**, 4, 783-795 ISSN: 2239-5938
Doi: 10.14207/ejsd.2026.v15n4p783

Transforming Waste Management from Incineration to Resource Recovery in the UK

By Habiba El-Gharably[1], Rufus Henderson[2], Alfred Chinta[3], Ash Ahmed[4]

ABSTRACT:
Sustainable waste management is central to the UK's transition to the circular economy and to decarbonising healthcare supply chains. Within the NHS, high-temperature incineration remains a carbon- and cost-intensive route, often driven by over-classification of non-hazardous materials and limited segregation capacity. Furthermore, autoclaving of hospital waste adds a layer of carbon intensity to Scope 3 emissions of hospitals. This study evaluates a practical circular pathway that diverts selected non-hazardous consumables from incineration to segregation, validated sterilisation, and repurposing as a possible sustainable secondary input for engineering applications. Using an integrated sustainability framework, the paper combines policy analysis, process mapping, and scenario-based treatment-stage carbon and cost comparison of the baseline incineration pathway and the segregate–sterilise–repurpose pathway. The assessment is aligned with national targets to achieve a 20:20:60 split (HTI clinical waste: infectious waste: offensive waste) and tests how improved segregation and reclassification of suitable non-hazardous streams from healthcare codes (e.g., EWC 18 01 04 to 20 03 01) can reduce treatment-related carbon emissions and enable higher-value recovery. This proposed solution could support reductions in treatment-stage CO_2e emissions and disposal costs, while allowing higher-value recovery through better management and segregation of healthcare waste.

Keywords: waste materials, UK zero waste, circular economy, resource recovery, waste management, healthcare waste

1. Introduction

Waste management is a crucial component of an organisation's approach to sustainability because it has an impact on resource efficiency, regulatory compliance, operational cost, and environmental impact. Waste generation usually increases in volume and complexity as service systems change and consumption patterns rise. This is especially true in the healthcare industry, where infection prevention and patient safety requirements heavily rely on the use of single-use consumables, such as personal protective equipment (PPE) and related clinical devices. Although these items are necessary for service delivery, their end-of-life management has become a growing sustainability concern because of the cost and carbon intensity of treatment routes, as well as the practical limitations of segregation in busy clinical settings (Kenny & Priyadarshini, 2021; Ghaffari et al., 2026).

In England, NHS providers generate approximately 156,000 tonnes of clinical waste each year that is managed primarily through high-temperature incineration (HTI) or

[1]Sustainable Materials Technologist at NuGreen Ltd, working in partnership with Leeds Beckett University (UK) through a Knowledge Transfer Partnership (KTP).
[2]Sustainability Director at NuGreen
[3]Leeds Beckett University
[4]Head of Civil Engineering at Leeds Beckett University.

alternative treatment (AT). This volume of waste has been described as equivalent to more than 400 loaded jumbo jets of waste, which has a substantial environmental impact and results in high operating costs and carbon emissions (NHS England, 2023). Waste treatment route selection is not only a compliance choice, but also a carbon and cost decision: diverting low-risk materials into higher-intensity treatment methods can increase emissions (Zandieh et al., 2024) and energy consumption, reduce recovery opportunities and increase disposal costs.

The carbon footprint of healthcare waste is highly dependent on the treatment method and waste classification. Hazardous and infectious wastes are often processed with high-temperature incineration, but lower-risk offensive waste can be managed through lower-temperature EfW pathways. Globally, approximately 85% of healthcare waste is classified as non-hazardous, but risk-based classification can still lead to conservative treatment of non-hazardous waste, reducing segregation and recovery opportunities (Rizan et al., 2021; Attrah et al., 2022; Janik-Karpinska et al., 2023; Saleh & Eskander, 2020).

Therefore, alignment with the NHS England Clinical Waste Strategy and its 20:20:60 (HTI Clinical waste, infectious waste, offensive waste) target could support reductions in carbon- and cost-intensive treatment through improved segregation. By implementing this strategy, it will help to produce annual savings of approximately £11 million for the next 10 years (NHS England, 2023). However, there are many factors including behavioural, organisational, and infrastructural affecting correct segregation and classification of healthcare waste (Webb et al., 2024). These challenges indicate that effective waste-management practices at source could reduce over-classification of non-hazardous waste and enable greater value recovery.

Additionally, recovery options are controlled by current approaches to healthcare waste classification and coding. Healthcare waste streams in the UK and EU are given European Waste Catalogue (EWC) codes. The List of Waste/EWC codes is used to categorise waste as hazardous or non-hazardous and support identifying appropriate waste-management options, according to the broader WM3 technical guidelines (Environment Agency, 2021). This study's proposed solution is to enable higher value recovery and significantly reduce carbon emissions from treatment as part of growing demand for circular pathways by reclassifying suitable non-hazardous (offensive) waste streams from healthcare code EWC 18 01 04 to household waste code EWC 20 03 01 (Environment Agency, 2014). Diverting selected treated waste streams from incineration into engineered secondary inputs could reduce reliance on virgin natural raw materials. The practicality of these pathways depends on effective implementation, including risk-assessed segregation (NHS England, 2024), validated sterilisation, quality control, and supply chain viability, as well as maintaining carbon and cost advantages when the entire process is examined.

2. Background

In accordance with the waste hierarchy and the prioritisation of waste prevention, the UK's policy is positioned towards a circular economy, and environmental sustainability focuses on decreasing waste generation and increasing the reusing and recycling rate with

minimal waste classed as landfill or incineration as the last option (Department for Environment, Food & Rural Affairs, 2011). Healthcare settings continue to face difficulties despite regulatory improvements toward more sustainable waste management because effective classification and recovery rely on routine segregation practices at the point of generation. Inaccurate non-hazardous waste segregation in the NHS can be caused by obstacles such as a shortage of bins, a lack of space, staff time constraints, and uncertainty regarding the correct waste streams (Webb et al., 2024).

Offensive waste is significant since it is non-hazardous but may be handled conservatively through incineration. It can include discarded personal protective equipment (PPE), gloves, nappies, bandages, swabs, cotton, and other non-hazardous materials contaminated with body fluids. NHS England recognises that offensive waste is presently recovered through EfW, but no established recycling technology is available for this stream (NHS England, 2023). This provides an opportunity to investigate controlled recovery methods for appropriate treated material.

According to Rizan et al. (2021), disposal via high-temperature incineration (HTI) has the highest carbon footprint at 1,074 kg CO_2e per tonne, comprising 949 kg CO_2e/t from HTI processing plus 125 kg CO_2e/t from transport for clinical waste. In contrast, non-hazardous offensive waste treated by low-temperature incineration with EfW totals 249 kg CO_2e/t, including 167 kg CO_2e/t from EfW processing and 82 kg CO_2e/t from transport. Where waste is autoclaved and decontaminated before EfW, the footprint increases to 569 kg CO_2e/t, made up of 338 kg CO_2e/t for autoclaving, 167 kg CO_2e/t for EfW, and 64 kg CO_2e/t for transport (Rizan et al., 2021). The use of renewable power may minimise autoclaving's electricity-related carbon footprint, but overall operating emissions must still be addressed.

Although sand is an essential building resource, its extraction from quarries, rivers, and seabeds may have an adverse effect on the environment. According to the United Nations Environment Programme (UNEP, 2022), the world uses over 50 billion tonnes of sand annually, and by 2060, demand for construction sand is predicted to rise dramatically. Additionally, riverbeds, aquatic habitats, and wider ecosystems may be harmed by river sand mining (Rentier & Cammeraat, 2022). According to Sanusi et al. (2026), these demands have prompted research on substitute fine aggregates for concrete and other materials for construction.

3. Aim and Scope of Research

This article evaluates whether a segregate–sterilise–repurpose pathway for non-hazardous offensive healthcare waste in England can lower the carbon and financial burden associated with current treatment methods to support the national objective of increasing the proportion of waste correctly managed as offensive waste (NHS England, 2023). The baseline system includes segregation and packaging at the point of generation, internal handling and storage, transport, shredding where required, and treatment by EfW, with shredding only used when contractor procedures demand it.

The alternative approach employs steam sterilisation and shredding through a proposed regional recovery model to generate a treated, size-reduced output suited for

© 2026 The Authors. Journal Compilation © 2026 European Center of Sustainable Development.

regulated downstream handling and repurposing into construction-sector material uses. Using treatment-stage CO_2e per tonne and indicative cost per tonne as the main outputs, the study compares the baseline with alternative pathways (Rizan et al., 2021). The alternative treatment calculation uses the manufacturer's technical data for the sterilisation and shredding unit alongside the DESNZ UK electricity emissions factor (DESNZ, 2025; Shuttleworth & Trees, 2025). Sharps, medicines, anatomical waste, infectious waste, and chemically contaminated items that would not qualify as offensive waste are all excluded from the scope, which is restricted to eligible non-hazardous offensive waste (NHS England, 2024; Environment Agency, 2014). This paper's main objective is to evaluate if better resource recovery, healthcare waste decarbonisation, and behavioural changes in waste management practices could be supported by better segregation and recovery of eligible offensive waste.

This study addresses three research questions: (1) whether the proposed segregate–sterilise–repurpose pathway can reduce treatment-stage CO_2 emissions compared with baseline EfW treatment; (2) whether the concentration of offensive waste generation among high-producing NHS trusts supports a regional hub implementation model; and (3) what operational and regulatory factors must be addressed before wider implementation. The working hypothesis is that eligible non-hazardous offensive waste can be redirected from EfW into a regulated recovery pathway with lower treatment-stage emissions, provided that segregation, sterilisation validation, regulatory compliance, and material suitability are achieved. Feasibility is assessed using treatment-stage carbon performance, projected avoided baseline EfW treatment cost, geographical accessibility, regulatory compatibility, and evidence of potential construction-material application.

This paper's evaluation of carbon and costs is restricted to an initial treatment-stage comparison. It includes the reported offensive waste volumes from ERIC 2024/25, the baseline EfW treatment carbon factor and cost, the electricity demand for the proposed sterilisation and shredding process, and the DESNZ grid electricity emissions factor. Transport from NHS trusts to regional hubs, water consumption, labour, infrastructure, maintenance, storage, quality testing, expenses associated with regulatory compliance, rejected or contaminated loads, and downstream processing into construction products are not included. Due to the lack of validated project-specific data at this time, these elements were excluded. As a result, the findings should be taken as treatment-stage estimates rather than a full life-cycle assessment or final net cost saving.

4. Methodology and Implementation Pathway

4.1 Research Design

This study assesses the implementation of a regional segregate-sterilise-shred-repurpose pathway for eligible non-hazardous offensive healthcare waste in England using a comparative, secondary-data methodology. The goal of the suggested concept is to divert suitable offensive waste from traditional EfW treatment and transform it into a regulated secondary input for use in the construction industry. Due to commercial sensitivity, product-specific material performance findings are not provided in detail; nevertheless, preliminary testing for concrete and asphalt applications has been conducted, and this study concentrates on the waste-management, carbon, cost, and implementation aspects of the pathway. The study includes comparative carbon and cost evaluation, geographical

mapping, process mapping, waste-volume assessment, and the prioritisation of high-producing NHS trusts. The aim is to determine whether a regional recovery model may assist the NHS's goal of increasing the percentage of waste treated through the offensive stream under the 20:20:60 objective while lowering treatment-related CO_2 emissions and costs (NHS England, 2023).

4.2 Data Collection and Waste Volume Assessment

To determine the total amount of offensive waste produced by NHS trusts in England, the study used the Estates Returns Information Collection (ERIC) 2024/2025 dataset released by NHS England (NHS England, 2025). Estates and facilities statistics from NHS trusts, including ambulance trusts, throughout England are collected through the required annual ERIC return. The dataset was used to determine the overall amount of offensive waste produced during the 2024 - 2025 reporting period as well as to extract the reported offensive waste volumes for specific NHS trusts.

As part of data cleansing, the ERIC dataset was analysed to obtain offensive waste volumes reported at trust level for 2024/25. To allow comparison between trusts, reported values were standardised to tonnes per year. Trusts with missing or unreported offensive waste values were excluded from the ranked offensive-waste total. Where trusts had unusual organisational structures, such as ambulance trusts or multi-site reporting arrangements, the reported ERIC trust-level value was retained because the study aimed to reflect the dataset as submitted rather than reallocating waste between individual sites. To calculate the cumulative percentage, trusts were ranked from highest to lowest offensive waste generation, and the running total was divided by the national ERIC offensive-waste total. The top 75 trusts were selected because they accounted for approximately 80% of the total reported offensive waste.

4.3 Prioritisation Model Using the 80:20 rule

The 80:20 prioritisation methodology was used to determine which NHS trusts were responsible for the majority of reported offensive waste and, from a supply-chain perspective, to focus initial collection, hub-capacity planning, and implementation resources on the smaller group of trusts that generated the most offensive-waste volume. About 208 NHS trusts were included in the ERIC 2024/25 dataset, and a total of about 67,883 tonnes of offensive waste were recorded. Ranking trusts by reported offensive waste revealed that the top 75 trusts produced nearly 54,335 tonnes, accounting for over 80% of the total. As a result, this group was chosen as the primary implementation target for the proposed regional treatment and recovery model.

4.4 Regional Mapping Model

The seven NHS England regions including London, Southeast, Southwest, Midlands, Northwest, East of England, Northeast and Yorkshire were used to map the chosen NHS trusts. A suggested network of shared treatment and recovery hubs was created using the regional mapping. Hub locations were selected as preliminary planning points based on regional grouping, mapped trust locations, offensive-waste volumes, and centroid proximity; they are not proposed as final operational sites.

© 2026 The Authors. Journal Compilation © 2026 European Center of Sustainable Development.

Eligible offensive waste would be gathered from participating trusts and sent to a regional centre that serves nearby NHS institutions under the proposed approach. A steam sterilisation and shredding unit that can produce a treated, size-reduced output would be included in each hub. After undergoing the necessary quality tests, the processed material would be used as a secondary input for applications in the construction industry.

The main objectives of having a regional hub model are to achieve enough waste volumes to maintain a workable recovery facility and to reduce excessive transportation distances between NHS trusts and the recovery facility. The suggested locations are not the final facility sites but rather a preliminary network design framework. Prior to implementation, further evaluation would be required, including travel modelling, authorised waste capacity, storage requirements, and regulatory permissions.

4.5 Baseline and Alternative Pathway

Figure 1

Baseline Route and Alternative Route

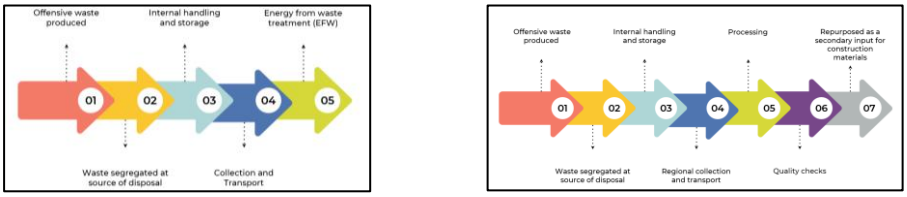


Figure 1 shows the baseline route currently used for NHS non-hazardous offensive waste, compared with the right figure, showing the alternative route proposed in this study. The scope is currently limited to eligible non-hazardous offensive waste stream.

5. Results

5.1 Offensive Waste Generation

The total amount of offensive waste which was produced by NHS trusts in England according to ERIC database 2024/25 is around 67,882 tonnes (NHS England, 2025). This demonstrates that offensive waste is a significant stream in NHS waste management and offers a significant chance for focused recovery and diversion.

5.2 High-Waste-Producing NHS Trusts

According to the 80:20 evaluation, 75 NHS trusts produced around 54,335 tonnes of offensive waste per year, accounting for over 80% of the entire ERIC offensive-waste volume. This supports a targeted deployment strategy that focuses on the highest-producing trusts before a wider national rollout.

5.3 Regional Distribution

The seven NHS England areas were used to map the top 75 NHS trusts to evaluate the amount of offensive waste generated as well as the geographic distribution of trusts. Table 1 displays the number of chosen trusts in each region, their regional

proportion, the total offensive waste created by those trusts, and the associated share of offensive waste.

Table 1

Regional Distribution of Top 75 NHS Trusts and Offensive Waste Generation

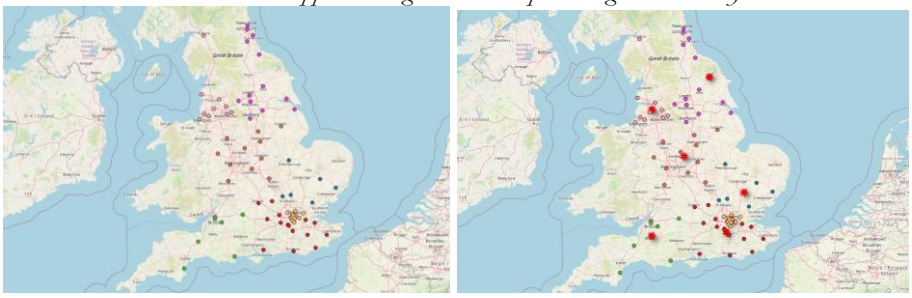
Region	NHS trusts	Trust share (%)	Waste (t/year)	Waste share (%)
London	13	17.3	12,175.56	22.4
Southeast	15	20.0	10,628.76	19.6
Southwest	7	9.3	3,663.87	6.7
Midlands	11	14.7	8,771.53	16.1
Northeast and Yorkshire	13	17.3	9,322.28	17.2
Northwest	10	13.3	6,128.78	11.3
East of England	6	8.0	3,644.65	6.7
Total	**75**	**100.0**	**54,335.43**	**100.00**

According to the table, with 20% of the top 75 trusts, the Southeast has the highest number of trusts. However, NHS trusts in London produce the highest amount of offensive waste 12,175.56 tonnes/year, accounting for 22.4% of the total offensive waste produced by the selected top 75 trusts. This suggests that the amount of waste being produced should be considered in addition to the number of trusts when determining regional planning. Together, London, the Southeast, and Northeast and Yorkshire account for 59.2%, that is a significant portion of the amount of offensive waste, indicating that the suggested hub model may need higher capacity treatment and recovery facilities in these areas.

Figure 2 maps the top 75 NHS trusts and indicative regional recovery hubs using NHS England regional groupings. These were colour coded such that they were divided into the 7 regions namely Southwest, Southeast, London, East of England, Midlands, Northwest, Northeast and Yorkshire. The hubs were estimated using trust locations, associated waste volumes, and centroid-based planning points to support preliminary regional consolidation.

Figure 2

75 NHS Trusts Mapped in England and Proposed Regional Recovery Hubs



Each trust was represented by its highest offensive-waste-producing location, and potential regional hubs were estimated using trust coordinates, waste volumes, and centroid-based planning. The QGIS travel-time plugin was used to create an initial two-hour accessibility screen rather than a final transport model. Route optimisation, vehicle

© 2026 The Authors. Journal Compilation © 2026 European Center of Sustainable Development.

payload and collection-frequency assumptions, storage and capacity checks, and detailed cost and carbon modelling would all be necessary for full implementation. Currently, 770L bins are used to store bagged waste for collection; future compactor-skip consolidation might increase load efficiency, but this requires a separate logistics assessment.

Figure 3

Travel Duration in the Southwest Region

Figure 3 illustrates the projected duration of 120 minutes from the centroid recovery hub to 7 NHS trusts in Southwest. This was completed for all 7 regions of NHS England.

5.4 Preliminary Treatment-Stage Carbon and Avoided Baseline EfW Treatment Cost

A comparison of the baseline EfW treatment route and the proposed sterilisation and shredding treatment step was conducted to evaluate the preliminary treatment-stage carbon saving and projected avoided baseline EfW treatment cost. Transportation, water use, equipment maintenance, labour, and downstream construction processes are not included in this calculation, which only concentrates on the treatment phase.

Based on available healthcare waste treatment data (Rizan et al., 2021; NHS England, 2025), the baseline approach provided a carbon factor of 167 kg CO_2e/t and a treatment cost of £391/t for offensive waste handled using EfW. The baseline treatment carbon emissions were calculated as follows for the 54,335.43 tonnes of offensive waste that accounts for 80% of the total offensive waste produced annually by the chosen top 75 NHS trusts:

54,335.43 t/year ×167 kg CO_2e /t = 9,074,016.81 kg CO_2e /year → 9,074.01 t CO_2e /year

The baseline treatment cost was calculated as:

54,335.43 t/year × £391/t = £21,245,153/year

The WSD400 sterilisation and shredding machine was modelled for the alternative treatment stage, with a rated throughput of 400 kg/h and an electricity consumption of 28 kWh for processing 0.4 tonnes of waste. This gives an estimated electricity demand of 70 kWh/t of waste treated (CISA Group, 2023).

28 kWh ÷ 0.4 tonnes = 70 kWh/t

The alternative route treatment-stage carbon impact was calculated using DESNZ UK grid average electricity factor of 0.17700 kg CO_2e/kWh (Department for Energy Security and Net Zero, 2025).

70 kWh/t × 0.17700 kg CO_2e/kWh = 12.39 kg CO_2e/t

The annual carbon impact of alternative segregate-sterilise-shred-repurpose pathway was calculated as follows:

54,335.43 t/year × 12.39 kg CO_2e/t = 673,216.98 kg CO_2e/year → 673.22 t CO_2e/year

Therefore, the annual treatment-stage carbon saving is:

9074.01 – 673.22 = 8,400.79 t CO_2e/year

This indicates a preliminary treatment-stage carbon saving of approximately 8,400.8 t CO_2e/year for the top 75 NHS trusts in England. The projected avoided baseline EfW treatment cost is approximately £21.25 million per year. Other operating costs of the alternative route, including water, maintenance, labour, transport, quality testing, and downstream handling, would need to be subtracted once verified cost data are available. Therefore, this should not be interpreted as a final net cost saving.

6. Discussion

The findings of the research demonstrate that the non-hazardous offensive waste stream offers a substantial chance for carbon reduction and circular recovery in NHS waste management. According to the ERIC 2024/2025 data, NHS trusts in England produced 67,882 tonnes of offensive waste (NHS England, 2025). The top 75 NHS trusts were found to produce 54,335.43 tonnes annually, around 80% of the offensive waste stream. This shows that a tailored strategy focusing on high generating trusts might serve as a feasible first step toward adoption.

Additionally, the geographical map shows that the distribution of offensive waste produced in England is unequal. A substantial proportion of the offensive waste stream comes from London, Southeast and the Midlands. This suggests that the future regional shared recovery hub should take waste amount and geographical distribution into account. This regional hub strategy is supported by the map of the 75 NHS trusts which shows the geographic grouping of highest-generating NHS trusts and the potential benefits of the shared recovery hub for nearby hospitals.

The mapping also serves to demonstrate how the suggested regional hub concept may be implemented in practice. In this study, each NHS trust's top offensive-waste-producing location was employed as the typical consolidation point, and the selected trusts were plotted using latitude and longitude coordinates. To identify possible recovery-hub planning sites, indicative regional centroid points were determined using the mapped trust locations. These centroid positions do not reflect final hub sites, but they do give a starting point for assessing regional demand, distance, and consolidation possibilities. This technique is compatible with wider research on healthcare logistics, which uses facility-location approaches to distribute demand points to service centres while taking capacity, accessibility, and operational efficiency into account (Kheybari et al., 2026).

© 2026 The Authors. Journal Compilation © 2026 European Center of Sustainable Development.

Figure 4
Trend of Offensive Waste Generated by NHS Trusts in England 2020–2025

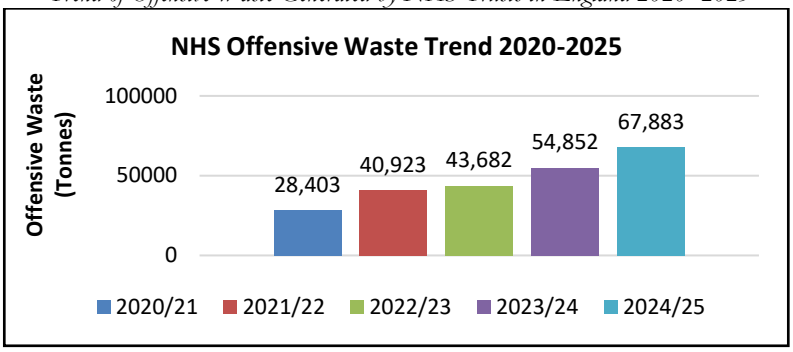


Figure 4 shows that reported offensive waste from NHS trusts in England increased from approximately 28,403 tonnes in 2020/21 to 67,883 tonnes in 2024/25, more than doubling over the five-year period (NHS England, 2025).

The NHS England Clinical Waste Strategy's broader growth expectations are in line with this growing trend. According to NHS England, the total amount of clinical waste processed by HTI and AT, along with offensive waste, may rise from around 149,000 tonnes in 2019/20 to almost 200,000 tonnes in 2029/30, assuming a 3% annual growth rate for waste arisings (NHS England, 2023). This emphasises how crucial it is to enhance segregation and find lower carbon recovery paths for appropriate non-hazardous offensive waste.

These findings are consistent with prior research, which has identified segregation behaviour, staff awareness, bin availability, and organisational routines as obstacles to sustainable hospital waste management (Webb et al., 2024; Quttainah & Singh, 2024; Baaki et al., 2025). However, this research expands on the subject by relating segregation improvement to a geographic implementation model as well as a treatment-stage carbon and cost comparison for offensive waste recovery (Rizan et al., 2021; Kheybari et al., 2026). In contrast to studies that primarily focus on waste-management behaviour, treatment-route emissions, or construction-material substitution, the current study incorporates waste-volume concentration, regional hub mapping, sterilisation requirements, and potential construction-material recovery (Attrah et al., 2022; Sanusi et al., 2026). Nonetheless, the conclusions are preliminary since the research does not yet include full logistical emissions, operating expenses, regulatory approval, or published material-performance data.

A key practical challenge is that the proposed alternative pathway depends heavily on correct segregation of offensive waste at the point of generation. Staff knowledge, training, behaviours, and routine waste-handling practices can all have an impact on the proper segregation and categorisation of healthcare waste (Quttainah & Singh, 2024). Recent data from a few NHS Trusts in Northwest England revealed limitations in segregation methods, a lack of regular training, and a lack of understanding of sustainable healthcare waste management techniques (Baaki et al., 2025). This shows that the success of the implementation of the proposed pathway relies on visible bins, waste auditing, clear

staff guidance, staff training, and compliance monitoring to recover a greater proportion of the offensive waste stream.

Figure 5

Circular Clinical Waste Model

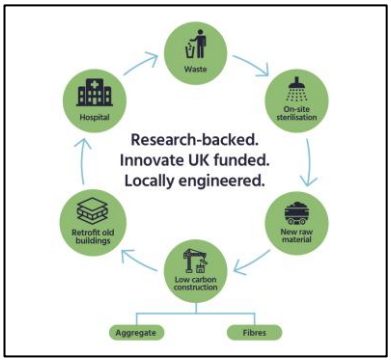


Figure 5 illustrates a fully circular clinical waste cycle starting with waste generated at source, which is the hospital, followed by sterilisation in the regional recovery hubs and then processed into new low-carbon materials for construction products including aggregates and fibres that can be used, for example, in retrofit applications for existing buildings.

7. Limitations

The findings should be viewed as preliminary treatment-stage estimates rather than whole-system net savings. Due to the lack of verifiable data for transport distance, collection frequency, vehicle payload, water usage, labour, maintenance, infrastructure expenses, rejection rates, quality testing, and downstream processing, a comprehensive quantitative sensitivity analysis was not conducted. To allow a complete life-cycle carbon assessment, life-cycle cost assessment, and sensitivity analysis, these metrics should be gathered in future pilot-scale studies.

8. Conclusion

This study evaluated the possibility of using a circular recovery pathway based on segregation, steam sterilisation, shredding, and repurposing as a secondary input for material applications in the construction industry instead of traditional energy-from-waste treatment for eligible non-hazardous offensive waste. The study was in line with the NHS England Clinical Waste Strategy, which aims to lower the carbon footprint of treating healthcare waste while increasing the correctly segregated offensive waste stream (NHS England, 2023).

The analysis indicates that there is a substantial recovery opportunity for offensive waste in NHS waste management. According to ERIC 2024/25 data, the top 75 trusts accounted for around 80% of the 67,882 tonnes of offensive waste produced by NHS trusts in England. Additionally, the regional mapping demonstrated the unequal

© 2026 The Authors. Journal Compilation © 2026 European Center of Sustainable Development.

distribution of waste generated, which supports the use of regional recovery centres as opposed to a single national approach.

Overall, the analysis indicates that offensive healthcare waste has the potential to help the NHS achieve its decarbonisation and circular economy objectives. Preliminary material testing with treated healthcare waste as a partial aggregate substitute in both concrete and asphalt applications showed positive results, indicating potential technical feasibility. However, this article does not provide the detailed performance data because of commercial sensitivity. As a result, while the treatment-stage carbon and cost assessment suggests a viable path forward, wider implementation would still necessitate the publication of material performance data, regulatory approval, pilot-scale validation, and additional assessment of transportation, operational, and downstream processing impacts. Correct source segregation, correct classification, validated treatment, regulatory approval, material testing, and acceptance of the treated product by the construction industry are all necessary for successful implementation.

References

Aquino, A. C. T. D., Gonçalves, M. F. S., & Mol, M. P. G. (2024). Healthcare waste and circular economy principles: It is time to improve! Waste Management & Research, 42(10), 857–859. https://doi.org/10.1177/0734242X241270979

Attrah, M., Elmanadely, A., Akter, D., & Rene, E. R. (2022). A review on medical waste management: treatment, recycling, and disposal options. Environments, 9(11), 146. https://doi.org/10.3390/environments9110146

Baaki, T. K., Wijekoon, C., Idowu, I., & Ganegodage, L. (2025). Understanding knowledge, perception, attitude and behaviour on sustainable healthcare waste management practices in selected National Health Service Trusts in the Northwest of England. Waste Management & Research, 43(11), 1760–1770. https://doi.org/10.1177/0734242X251374491

CISA Group. (2023). WSD Waste Sterilization Department: for healthcare applications, laboratories and scientific research facilities. https://cisagroup.it/wp-content/uploads/2023/03/P-WSD_P-WSM_Br_Eng_rev2_2023.pdf

Department for Environment, Food & Rural Affairs. (2011). Guidance on applying the Waste Hierarchy. https://assets.publishing.service.gov.uk/media/5a795abde5274a2acd18c223/pb13530-waste-hierarchy-guidance.pdf

Department for Energy Security and Net Zero. (2025). 2025 government greenhouse gas conversion factors for company reporting: methodology paper for conversion factors: final report. https://assets.publishing.service.gov.uk/media/6846b0870392ed9b784c0187/2025-GHG-CF-methodology-paper.pdf

Environment Agency. (2014). Healthcare and related wastes: how to classify. https://www.gov.uk/guidance/healthcare-and-related-wastes-how-to-classify

Environment Agency, Natural Resources Wales and Scottish Environment Protection Agency. (2021). Waste classification: guidance on the classification and assessment of waste. Technical Guidance WM3. (1st ed., Version 1.2.GB). https://assets.publishing.service.gov.uk/media/6152d0b78fa8f5610b9c222b/Waste_classification_technical_guidance_WM3.pdf

Ghaffari, M., Hupponen, M., & Horttanainen, M. (2026). Life cycle assessment of the healthcare plastic waste management in Finland, a case study: HUS Meilahti hospital area. Waste Management, 218, 115528. https://doi.org/10.1016/j.wasman.2026.115528

Janik-Karpinska, E., Brancaleoni, R., Niemcewicz, M., Wojtas, W., Foco, M., Podogrocki, M., & Bijak, M. (2023). Healthcare waste—a serious problem for global health. Healthcare, 11(2), 242. https://doi.org/10.3390/healthcare11020242

Kenny, C., & Priyadarshini, A. (2021). Review of current healthcare waste management methods and their effect on global health. Healthcare, 9(3), 284. https://doi.org/10.3390/healthcare9030284

Kheybari, S., Mehrpour, M. R., Moradi, N., & Scaparra, M. P. (2026). Optimizing vaccination facility locations and capacity as a pandemic response: A case study of Mashhad, Iran. International Journal of Production Economics, 292, 109865. https://doi.org/10.1016/j.ijpe.2025.109865

NHS England. (2023). Clinical waste strategy. https://www.england.nhs.uk/wp-content/uploads/2023/03/B2159i-nhs-clinical-waste-strategy.pdf

NHS England. (2024). Health Technical Memorandum 07-01: Safe and sustainable management of healthcare waste. https://www.england.nhs.uk/wp-content/uploads/2021/05/B2159iii-health-technical-memorandum-07-01.pdf

NHS England. (2025). Estates Returns Information Collection, summary page and dataset for ERIC 2024/25. https://digital.nhs.uk/data-and-information/publications/statistical/estates-returns-information-collection/summary-page-and-dataset-for-eric-2024-25

Quttainah, M. A., & Singh, P. (2024). Barriers to sustainable healthcare waste management: A grey method approach for barrier ranking. Sustainability, 16(24), 11285. https://doi.org/10.3390/su162411285

Rentier, E. S., & Cammeraat, L. H. (2022). The environmental impacts of river sand mining. Science of the Total Environment, 838, 155877. https://doi.org/10.1016/j.scitotenv.2022.155877

Rizan, C., Bhutta, M. F., Reed, M., & Lillywhite, R. (2021). The carbon footprint of waste streams in a UK hospital. Journal of Cleaner Production, 286, 125446. https://doi.org/10.1016/j.jclepro.2020.125446

Saleh, H. M., & Eskander, S. B. (2020). Introductory Chapter: Hazardous wastes. In H. M. Saleh & S. B. Eskander (Eds.), Assessment and Management of Radioactive and Electronic Wastes. IntechOpen. https://doi.org/10.5772/intechopen.88600

Sanusi, A., Ndububa, E. E., Amuda, A. G., Obianyo, I. I., Ahmed, A., Adeleke, W. A., ... & Mambo, A. D. (2026). Replacing river sand in concrete: A review of emerging sustainable fine aggregate materials. Discover Sustainability, 7, 346. https://doi.org/10.1007/s43621-026-02686-z

Shuttleworth, F., & Trees, L. (2025). Methane and net zero. Part 1: an introduction to net zero, methane, metrics and ruminants. In Practice, 47(6), 310–317. https://doi.org/10.1002/inpr.558

United Nations Environment Programme. (2022). Sand and sustainability: 10 strategic recommendations to avert a crisis. United Nations Environment Programme. https://www.unep.org/resources/report/sand-and-sustainability-10-strategic-recommendations-avert-crisis

Webb, C., Anguilano, L., & Schmidt Rivera, X. (2024). A pilot study into the use of qualitative methods to improve the awareness of barriers to sustainable medical waste segregation within the United Kingdom's national health service. Sustainability, 16(7), 3027. https://doi.org/10.3390/su16073027

Zandieh, Z., Thornley, P., & Chong, K. (2024). Progress of waste management in achieving UK's net-zero goal. Journal of Material Cycles and Waste Management, 26(5), 2601–2619. https://doi.org/10.1007/s10163-024-02003-8

© 2026 The Authors. Journal Compilation © 2026 European Center of Sustainable Development.