Life-cycle assessment of waste management options

In a nutshell

Summary overview							
It is BEMP to embed life-cycle thinking and assessment into waste management strategy and operations, with steps 1 and 2 (below) being essential and steps 3 to 8 needing an ad-hoc life-cycle assessment (LCA) to be carried out and not always necessary: 1. Systematic application of life-cycle thinking throughout waste management strategy design and implementation (to complement the waste management hierarchy). 2. Review of relevant LCA literature to rank the environmental performance of alternative waste management options, where studied systems are directly comparable with available options. 3. Application of LCA to specific management and technology options for which no reliable published literature can be found; this requires procurement of LCA services, or in-house use of relevant LCA software. 4. Careful consideration of system boundaries to ensure an accurate comparison across options, including system expansion and/or LCA for avoided processes (e.g. grid electricity generation). 5. Compilation and documentation of life-cycle inventories in relation to reference flows, if possible using primary data recorded along the value chain, noting data quality and uncertainty ranges. 6. Selection of pertinent impact categories to capture the major environmental burdens. 7. Presentation of normalised results for relevant impact categories to evaluate complementarities or trade-offs, with clear indication of uncertainty errors and sensitivity analyses. 8. Validation of the LCA study by an independent third party (essential requirement under ISO 14044 for external dissemination of results, but good practice even when only used internally).							
Waste management area							
Cross-cutting	**MSW - strategy**	**MSW - prevention**	**MSW - collection**	**MSW - EPR**	**MSW - treatment**	**CDW**	**HCW**
Applicability							
A full life-cycle assessment is not always necessary. Basic prioritisation of the waste management options indicated in the waste management hierarchy may be sufficient to inform best practice in some cases. However, detailed comparison of options ranked similarly in the waste hierarchy, and of management changes that affect the overall waste chain performance are often required. Waste management organisations of any size may apply life-cycle thinking and review LCA studies. Buying bespoke LCA services and/or paying for staff training in LCA may only be economically viable for larger organisations.							

Specific environmental performance indicators
• Systematic application of life-cycle thinking, and, where necessary, undertaking of life-cycle assessments, throughout waste management strategy design and implementation (y/n).
Benchmark of excellence
• The waste management strategy is designed and implemented on the basis of systematic application of life-cycle thinking and, when needed, ad-hoc life-cycle assessment studies.

Description

Why undertake a life-cycle assessment?

Life-cycle assessment (LCA) was pioneered in the 1970s and 1980s to evaluate the environmental efficiency of packaging options (Hunt et al., 1974; Boustead, 1989), and has since developed further for wider application such as the comparison of different waste management options (White et al., 1995). LCA provides a comprehensive framework to evaluate the overall resource and environmental efficiency of different waste management strategies, practices and technologies (ISO, 2006a). Crucially, indirect and upstream effects, such as raw material extraction, transport and processing to replace resources removed from circulation in the economy, are accounted for in LCA, thus enabling comparison of recycling and extraction of virgin raw materials for example.

The waste hierarchy provides clear guidance on the prioritisation of management options. However, in order to compare the environmental efficiency of options within the same stratum of the waste hierarchy, or that transcend strata (e.g. anaerobic digestion that both *recycles* nutrients and *recovers energy* via biogas), LCA may be required. In particular, the move towards a circular economy, with circular flows of materials through multiple recycling loops and material to energy transformations (e.g. refuse-derived fuels, biogas and wood chips), necessitates an "expanded-boundary" LCA approach that considers for example the avoidance of fossil energy generation associated with use of biogas.

From a strategic policy perspective, "consequential LCA" may be the most appropriate framework to evaluate the *net environmental change* associated with prospective waste management strategies that are likely to involve multiple product outputs and multiple system substitutions and indirect (market) effects (Weidema, 2001, Ekval and Weidema, 2004).

Thus, life-cycle thinking and LCA are crucial elements of best practice in devising integrated waste management strategies, and are integral components of strategic environmental assessments undertaken by local authorities to evaluate development plans in relation to national sustainability targets.

Best practice measures

The steps below represent important best practice measures to successfully embed life-cycle thinking and assessment into waste management strategy and operations. Steps 1 and 2 represent essential minimum requirements for best practice that may be undertaken universally by any waste management organisation (however small) to ensure that operations are fully informed by life-cycle thinking. Steps 3 to 8 involve the undertaking of an LCA study, and are only necessary where conclusions from published studies are not transferable to the options being compared by the waste management organisation.

1. Systematic application of life-cycle thinking throughout waste management strategy design and implementation, wherever necessary to augment the recommendations of the waste management hierarchy.
2. Review of relevant LCA literature to rank the environmental efficiency of alternative waste management options, where studied systems are directly comparable with available options.
3. Application of LCA to specific management and technology options for which no reliable published literature can be found, procurement of LCA services, or in-house use of relevant LCA software.

4. Careful consideration of system boundaries to ensure an accurate comparison across waste management options, including system expansion and/or application of consequential LCA to account for avoided processes (e.g. grid electricity generation) where appropriate.
5. Thorough compilation and transparent documentation of life-cycle inventories in relation to reference flows, using primary data recorded by organisations along the value chain where possible, and noting data quality and uncertainty ranges.
6. Selection of pertinent impact categories to capture the major environmental burdens.
7. Presentation of normalised results for relevant impact categories to evaluate complementarities or trade-offs, with clear indication of uncertainty errors and sensitivity analyses around variable parameters.
8. LCA studies should be validated by an independent third party (essential requirement according to ISO 14044:2006 'Environmental management - Life cycle assessment - Requirements and guidelines' for external dissemination of results, but good practice even when results are only used internally).

Environmental benefits

Embedding life-cycle thinking and LCA into strategic planning and technology selection decisions can maximise environmental efficiency and reduce overall direct and indirect (life-cycle) environmental burdens. The realisation of environmental benefits referred to throughout this report, in Chapter 1 and subsequent BEMP techniques, is at least partially attributable to life-cycle (systems) thinking and assessment.

Side effects

Consideration of life-cycle performance across waste management strategies and technologies should help to minimise cross media effects.

The process of normalisation may be helpful to evaluate trade-offs across impact categories associated with cross-media effects.

Expansion of the LCA scope to undertake social LCA can identify any trade-offs between environmental, economic and social pillars of sustainability.

Applicability

Life-cycle assessment is not always necessary. Basic prioritisation of waste management options indicated in the waste management hierarchy may be sufficient to inform best practice in some cases. However, detailed comparison of options ranked similarly in the waste hierarchy, and of management changes that affect whole-waste-chain performance, is often required.

Waste management organisations of any size may apply life-cycle thinking and review LCA studies. Buying bespoke LCA services and/or paying for staff training in LCA may only be economically viable for larger organisations.

Economics

LCA software and database access costs for commercial entities vary depending on the purpose of use and the number of individual (staff) users. Software licence fees are often bundled with database access fees and service contracts that provide support, software and database updates. For example, one provider offers commercial licences ranging from EUR 2 400 for a single-user “report maker” licence to EUR 22 000 for a multi-user developer licence (PRé Consultants, 2015).

Effective use of open-access LCA software such as Open LCA may require the purchase of a database access licence, and/or staff training: e.g. the Technical University of Denmark provides training courses in the use of EASETECH for EUR 5 000 per person.

Undertaking in-house LCA studies will also require significant staff time that should be accounted for in project costs. Alternatively, procurement of LCA services from a consultancy or academic institution is likely to cost tens of thousands of euros, but could avoid costs associated with licensing and staff time.

Efficiency benefits associated with systems thinking and optimisation informed by LCA could be orders of magnitude greater than these costs, but may be difficult to attribute directly.

Driving forces for implementation

Waste management organisations may apply life-cycle thinking and assessment to:

- improve operational efficiency;
- reduce environmental impacts and potential liabilities;
- demonstrate the sustainability of their operations to stakeholders;
- comply with corporate social responsibility and stakeholder reporting obligations.

Reference organisations

Aschaffenburg local authorities demonstrate comprehensive and systematic life-cycle thinking in their waste management strategy.

The Technical University of Denmark (DTU) is a well-known organisation in LCA accounting for waste systems, and it provides software tools and training for waste managers.

An LCA study was undertaken to compare the current situation of MSW incineration in the Aalborg county of Denmark with an alternative scenario of anaerobic digestion of the separated organic fraction (Hill, 2010). The results of the LCA indicated that the current situation is the better option from an environmental perspective if the anaerobic digestion plant is managed in a “typical” manner, but that anaerobic digestion could be the better option if it is managed in accordance with best practice recommendations – highlighting the sensitivity of LCA results to operational parameters and assumptions.

Literature

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