

# Environmental systems perspective on ash utilization and tools for decision support

*Susanna Toller*

*PhD Susanna Toller, Ecoloop AB, Mosebacke Torg 4, 116 46 Stockholm, susanna.toller@ecoloop.se*

**Abstract** The aim of this paper is to discuss the system boundaries for environmental assessment of ash utilisation, outline a framework for life cycle thinking within the planning process for ash utilisation and to give examples on how it may be performed. A life cycle perspective on ash management is required in order to provide a basis for decisions which do not imply any export of problems to other geographical areas or future generations. It may be applied in specific projects or on a more general level in which a policy or strategy to be used in several projects is the main scope. At both system levels, the use of a life cycle perspective contributes with useful information at different phases of the decision process.

*Keywords: Life cycle perspective, LCA, decision support, re-use, residues*

## INTRODUCTION

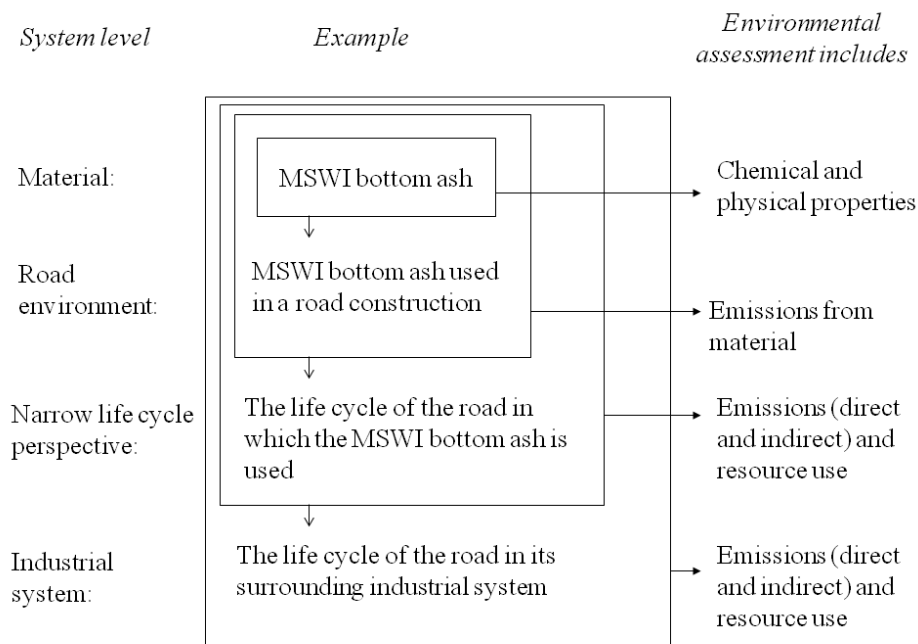
In Sweden, utilisation of combustion residues such as ashes outside disposal areas is restricted by environmental concerns, as such residues commonly contain greater amounts of potentially toxic trace elements than the natural materials they replace. On the other hand, utilisation can also provide environmental benefits by improving the function of a construction and/or reducing the use of “virgin” raw material and the environmental burdens from its extraction and transport. An environmental systems analysis that applies a life cycle perspective is required in order to capture both the benefits and environmental burdens in environmental assessment of ash management, and to provide a basis for decisions which do not imply any export of problems to other geographical areas or future generations.

Life cycle thinking is currently becoming a fancy term in a number of situations as stakeholders strive towards using a life cycle perspective in decision situations. A life cycle perspective enables potential environmental impact to be considered regardless of where and when it occurs. Thus, a life cycle perspective enables environmental assessments to expand from a narrow system perspective in which only site specific aspects such as impact on biodiversity or toxic risks are included, towards considering resource use and emissions occurring on a regional or global scale, as required by the Swedish Environmental Code. In terms of sustainable development, a life cycle perspective is necessary in order to achieve the environmental objectives [1] without exporting problems to future generations or abroad. In other words, using a life cycle perspective is a key to a more system effective society with long term sustainable solutions that do not hinder future growth. By using a life cycle perspective, stakeholders in different decision situations has the potential to increase the quality of environmental work and, consequently, the competitiveness of individual companies and agencies as well as Sweden as a country.

Although a life cycle perspective is often desired it is not always clear how it should be applied. There are several methodologies and associated tools available for providing decision support based on life cycle thinking. The application of these (choice of tools, system boundaries etc.) depends both on the system level on which the decision is to be made and on where in the decision process the information is needed. The aim of this paper is to discuss the system boundaries for environmental assessment of ash utilisation, outline a framework for life cycle thinking within the planning process for ash utilisation and to give examples on how it such an assessment may be performed.

## SYSTEM BOUNDARIES FOR ENVIRONMENTAL ASSESSMENT

Environmental assessment of the use of waste materials or by-products in construction can be made with different system boundaries that imply different levels of complexity. These levels may be distinguished as the i) material level, ii) road environment level, iii) narrow life cycle level and iv) industrial system level, as suggested by Roth and Eklund [2]. This thinking can be applied on the utilisation of ashes [3] (fig. 1). By studying the material, information can be gained about its chemical and physical properties. If we want to say anything about the emissions and their potential impact, we have to include the context in which the material is used. Still, however, we can only evaluate direct emissions from the material, and nothing is known about the more indirect impact that arises from substituting a natural material with the ash. Knowledge on the chemical properties of a material is necessary when assessing the risk for local environmental effects (i.e. toxic effects), but is not sufficient if a wider range of aspects are to be covered, such as climate change, acidification, eutrophication and depletion of natural resources. To include different types of environmental impact, we have to expand the system boundaries further and compare different scenarios for ash management in a life cycle perspective. Ash utilisation may also be seen within the context of the energy producing system, through which the ashes are formed. Such a perspective requires even broader system boundaries, the industrial system level according to the terminology previously suggested [2], as the whole energy production system then needs to be included. Each system level for environmental assessment has its advantages and drawbacks. Whereas narrow system boundaries provide detailed and validated information of a limited part of the system studied, a broader view with less precision is sometimes needed in order to obtain relevant results and to avoid non-optimal or contra productive decisions that export environmental problems in time or geographically [4].



**Figure 1.** Different system levels on which environmental assessment of the utilisation of ashes can be made with solid waste incinerator (MSWI) bottom ash in a road construction as example (adapted from [2]).

Within the area of life cycle thinking research is being performed at universities and research institutes in Sweden and internationally. As a result, concepts for applying a life cycle perspective has evolved and a method for life cycle assessment (LCA) has been developed and standardized [5], in order to ensure “good practice” when being used for arguing the benefits of specific products or production processes. Much of the previous research within life cycle thinking has been focused on LCA methodology questions regarding for example allocation principles, the potential impact and consequences to be expected as a result of certain pressures (emissions), and the improvement of databases. Life cycle perspective has also frequently been used within research for environmental

assessment of different alternative solutions or strategies to achieve a certain function. Tools for LCAs have been developed, but there are also a wide range of approaches within sustainability research that might be argued to apply a life cycle perspective although not performing strict LCAs.

Although a life cycle perspective has been applied on a number of questions for research purposes, the practical use within decision situations, i.e. in the built society, is limited. There is, for example, a great uncertainty regarding what tools and methods to trust and how to manage the complexity that arises when expanding the system boundaries towards upstream and downstream impacts. For decisions regarding ash utilisation, certain questions are belonging to different phases of the decision process. An understanding of the decision process and the efficient use of environmental assessment tools within this process is therefore necessary in order to enable a life cycle perspective to be successfully applied.

### SUGGESTED FRAMEWORK FOR APPLYING A LIFE CYCLE THINKING ON ASH UTILISATION

Within a framework for decision making, life cycle thinking may be applied in at least four different decision situations (fig. 2). It may be implemented in specific projects or on a more general level in which a policy or strategy to be used in several projects is the main scope. It may also be implemented within an early phase of the planning process or within detailed planning of a project in which design and other optimisation issues are considered. For each specific system level and phase of decision process, principles and examples of how to apply a life cycle perspective need to be developed. However, information exchange and integration between these levels and phases is also needed. For example, information obtained on a national system level needs to be utilized in order to identify important issues in environmental assessments on a project level.

General/ national	Objectives and targets, prioritising criterias/ aspects of importance	Permit application practice, policies and guidelines
Project	Identifying options, screening evaluation	Identifying best available technology, optimising design
Decision level Decision phase	Problem investigation and analysing options	Optimising options

**Figure 2.** Framework for decision making in which life cycle thinking can be applied.

Development of ash utilisation practice that enables utilisation in a way that is consistent with international environmental legislation and the Swedish environmental quality objectives involves a number of stakeholders. Most central on a project level are the ash producer (the incinerator owner), the operator that utilises the ash (for example for the purpose of construction or for nutrient recycling on forest land) and the local authority. On a national level, on the other hand, national authorities and trade associations have an important influence.

On a project level, a life cycle perspective may be a valuable tool within the process of identifying and evaluating different options. For example, a comparative life cycle assessment may be performed for different alternative materials, including ash, for a certain construction or other type of service/function that is wanted. There are several examples of such life cycle assessments for constructions with incinerator residues [6,7,8,9]. In this phase, it is sometimes useful to exclude those parts of the system that are similar for the compared options in order to save time and resources but also to emphasise

the differences between the studied options. For example, if the asphalt layer will be the same regardless of sub-base material, the asphalt layer might be excluded from the study if different materials for the sub-base layer are to be compared. As the asphalt production is relatively energy intense due to the bitumen production, it might otherwise conceal the differences that depend on the sub-base material.

In a later phase of the planning, the focus may shift towards optimising the process that has already been decided on. Then a life cycle assessment might be a useful tool in order to identify “hot spots” for environmental impact and enable for efficient measures to be taken where needed. At this phase a stand-alone type of assessment would be most appropriate as it is now important not to exclude any parts of the system that contributes to the environmental impact. A comparative assessment might, however, also be useful but it is then important to bear in mind that parts that were excluded from the comparison might also be important for the “hot spot” identification. Given the example with asphalt above, it is important to consider the asphalt production as this may well be more important for the overall impact on greenhouse gas emissions from the system than any other activities within the system. If that is the case, effective measures for reducing environmental impact may be those that decreases the thickness demand of the asphalt layer or increases the time span between rehabilitation activities.

When ashes are used for construction purposes in Sweden, the Swedish Environmental Code requires that operators obtain a permit from the local environmental authorities. According to a number of interviewed local authorities involved in permission processes for ash utilisation, Toller et al. [10] found that a life cycle perspective (on a project level) is necessary in order to meet some of the demands that are expressed by the legislation. Both types of assessments described above may provide valuable information for the environmental impact assessment (EIA) that is required within a permit application. They need, however, to be combined with site specific risk assessment as they are less useful to capture dose-response issues regarding leaching from the material at the specific site of interest. Whereas the comparative assessment is needed in order to show the resource use effectiveness obtained by the re-use, a stand-alone assessment is useful to show how the operator plan to minimise the potential environmental impact by effective measures. For the communication within the permit application process to be successful, however, it was also concluded in [10] that the different stakeholders (the ash producer, the operator, and the local authority) involved in the permitting process have very different starting-points and that these needs to be understood for the process to be effective and consistent from case to case. Whereas the ash producer has in depth knowledge of the chemical and physical properties of the material, and a strong economic interest in utilisation, the operator can often choose between different types of material of which the ash is only one, and the interest of using ash is rapidly decreasing if it implies a complicated permission procedure or increased expenses. For the local authority, finally, the ashes are not very well known and as the environmental benefits from the utilisation are seldom quantified, the authority is often restrictive regarding utilisation. To achieve an efficient and consistent decision process in line with current legislation and national goals, [10] concluded that the communication between these stakeholder groups needs to be improved regarding joint goals and strategies for utilisation of ashes.

Whereas project level assessments are useful to obtain information about specific cases, the national perspective is more appropriate for comparing different strategies in a broader scenario context. Such a comparison is valuable as a basis for evaluating policies and plans in a strategic environmental assessment (SEA), or for communication between different stakeholder groups, i.e. for discussing joint goals and strategies for ash utilization according to the needs described above. To generate general policies on ash utilization, for example, one interesting question is what the environmental benefits and drawbacks are from different ash management scenarios on a national scale. The focus is then the material, which may be managed in several ways, rather than the produced function (i.e. a construction). Such an approach has been outlined in [11]. It was also used in the consequential analysis [12], that was performed as a reaction on the criterias for reuse of waste in constructions that were suggested by the Swedish Environmental Protection Agency 2007. The analysis contained a life cycle assessment part that was based on generalized case studies of different ashes and no major changes in the surrounding system (the industrial system) was assumed [13]. It should not be neglected, however, that future changes in ash management may have an impact on the whole industrial system, i.e. regarding combustion practice or available energy sources for electricity production, that may affect the outcome of the assessment.

In a later planning phase, a relevant question on the national level could be what to focus on in the permit application of ash utilization. What is important and what is less important when the expected

environmental impact is described? In [10] it was concluded that besides the need for increased communication, there is also a need for coordination within each stakeholder group on a national or regional level if the permit process of ash utilisation is to be performed effectively and in the line with national legislation and environmental goals. There were large differences nationally regarding the information that was requested by the local authorities and it was also stated that the background information provided by the ash producers sometimes suffer from a bad quality. To ensure consistency within the country and to avoid unnecessary work in each specific cases, a national approach rather than a project specific approach for solving these problems is suggested. By using scenario analyses performed on the early planning phase, i. e. for communication purposes, general “hot spots”, sources of sensitivity and importance of different impact categories or emissions can be drawn out. For comparing the relative importance of different types of environmental impact there are different weighting methods to be used, including the use of normalisation as demonstrated by [11].

## CONCLUSIONS

Life cycle thinking contributes to decisions that aim for long term sustainable development in which problems are not transferred to other geographical areas or future generations. However, life cycle thinking needs to be combined with other environmental assessment tools, such as site specific risk assessment and broad studies on the industrial system in which the ashes are formed.

Life cycle thinking can be applied on ash utilisation in a different ways depending on where in the planning process and on what system level decisions support is needed. A national system levels is appropriate when evaluating general policies and programs within a strategic environmental assessment, and to sort out what is important to measure. The project level, on the other hand, is useful when identifying promising options to enable a certain function or as a basis for the environmental impact assessment requested in a permit application process of a specific project.

## REFERENCES

- [1] Environmental Objectives Council. Sweden's Environmental Objectives: No time to loose. The Environmental Objectives Council, Stockholm, Sweden, 2008.
- [2] Roth, L. and Eklund, M. Environmental evaluation of reuse of by-products as road construction materials in Sweden. *Waste Management* 23, 2003, Pg 107-116.
- [3] Olsson, S. Environmental assessment of municipal solid waste incinerator bottom ash in road constructions. Licentiate thesis, TRITA-LWR.LIC 2030, KTH, Stockholm, Sweden, 2005.
- [4] Toller, S. Environmental assessment of incinerator residue utilisation. TRITA-LWR PhD Thesis 1046, KTH, Stockholm, Sweden, 2008.
- [5] ISO 14040 International Standard. In: *Environmental Management – Life Cycle Assessment – Principles and Framework*. Geneva: International Organisation for Standardization, 2006.
- [6] Birgisdóttir, H., Bhandar, G., et al. Life cycle assessment of disposal of residues from municipal solid waste incineration: Recycling of bottom ash in road construction or landfilling in Denmark evaluated in the ROAD-RES model. *Waste Management* 27(8), 2007, Pg 75-84.
- [7] Carpenter, A. C., Gardner, K. H., et al. Life cycle based risk assessment of recycled materials in roadway construction. *Waste Management* 27, 2007, Pg 1458-1464.
- [8] Mrueh, U.-M., Eskola, P. et al. Life-cycle impacts of the use of industrial by-products in road and earth construction. *Waste Management* 21, 2001, Pg 271-277.
- [9] Olsson, S., Kärrman, E. et al. Environmental systems analysis of the use of bottom ash from incineration of municipal waste for road construction. *Resour. Conserv. Recycl.* 48(1), 2006, Pg 26-40.
- [10] Toller, S., Johansson M. et al. Lätt att göra rätt, beslutsunderlag för miljöprövning av askor i anläggningar. Miljöriktig användning av askor 1170, Värmeforsk Service AB, Stockholm, Sweden, 2011.
- [11] Toller, S., Kärrman, E. et al. Environmental assessment of incinerator residue utilisation. *Waste Management*, 29(7), 2009, Pg 2071-2077.
- [12] Avfall Sverige. Miljökonsekvensanalys av Naturvårdsverkets förslag till kriterier för återvinning av avfall i anläggningsarbeten. Rapport F2008:04, Avfall Sverige, Sweden, 2008.
- [13] Olsson, S., Livscykelperspektiv på återvinning av askor. Fjärrsynsrapport 2008:4. Svensk Fjärrvärme, Sweden, 2008.