SUMMARY OF MAIN FINDINGS

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**AIM OF THE PROJECT**

One of the cornerstones of a circular economy is that our welfare has to rely more on recycled materials than on primary production, not only due to environmental reasons but for (geo-)political and economic consequences of universal changes such as climate change and resource scarcity as well. Such an understanding implies multiple challenges for society in general and for the recycling sector in particular, which gradually needs to evolve into a more important raw material supplier.

Today, however, most recycling processes are optimized to recover one or a few targeted outputs and their operations therefore generate large amounts of by-products such as ashes, slags, and other heterogenic materials. Such residues typically consist of a blend of valuable, organic, inert, and hazardous components, making them technically challenging and economically unappealing to recover. Many of our current recycling systems therefore only valorise a fraction of the materials contained in the waste streams, while the remains are either downcycled to low quality applications or disposed of in landfills. Beyond adding disposal costs to the recycling industry, such a practice leads to continuous losses of natural resources.

The aim of this project is to contribute knowledge for facilitating valorisation of such heterogenic residues in Sweden. In doing so, we study the resource potential and multifaceted challenges for valorisation of a specific and fine-grained residue in terms of shredder fines, which is generated from the recycling of end-of-life vehicles and other scrap. By synthesizing these results and by analysing which overall functions and conditions that are required to establish markets for waste-based materials, potential measures to stimulate and support the development of valorisation options for heterogenic residues are discussed.

**THE CONDUCTED STUDIES AND THEIR CONTRIBUTIONS**

The project has involved several studies addressing the materiality of shredder fines and the technical, organizational, policy and market conditions influencing the management of this material as well as other similar residues. In this chapter, some of the key studies are briefly introduced in terms of their focus and main contributions.

**Mapping current knowledge levels and gaps**

This study involved a systematic review of previous literature on shredder fines and its management, which aimed at guiding future research regarding the valorisation of this heterogenic residue. The results show that although shredder fines have been studied for decades, the research is still in a very early stage of development. Virtually all of the research is technically focused involving either the characterization of some selected physical or chemical properties of a few random samples of the material or the development of different treatment and resource recovery processes at lab-scale. Both of these types of studies display
large limitations when it comes to the scope and applicability of their findings. For instance, the process development studies have often employed a narrowly conceived objective of addressing only one resource recovery opportunity or contamination problem at a time. Hence, the full recovery potential of shredder fines has been overlooked.

In essence, this study concludes several important knowledge gaps when it comes to the materiality of shredder fines and the applicability of the studied treatment and resource recovery processes. The research can also be characterized as largely topical, where the studies typically only deal with one aspect of fines or its management at a time. This lack of a system perspective is an important limitation as it disregards that changing current disposal practices and achieving valorisation of shredder fines is a multi-faceted challenge influenced by several interrelated technical, organizational, market and policy conditions.

**Assessing the resource potential to guide future process development**

The aim of this study was to develop a more comprehensive understanding about the physical and chemical properties of shredder fines, how such characteristics vary over time and are distributed through different particle sizes of the material. This to provide tangible knowledge for facilitating development of tailored upgrading and resource recovery processes. Shredder fines from a specific plant was therefore strategically sampled over time to obtain both average values and variations of a wide range of physical and chemical properties. The material characteristics of fines were then benchmarked against the gate and regulatory requirements of five potential applications for the material. In essence, the results show that fines has a significant resource potential in terms of potentially recoverable metals, energy carriers and minerals. However, this potential is currently limited due to several material constraints that needs to be resolved simultaneously to enable resource recovery.

An overall contribution from this study is that it clearly demonstrates that the realization of the resource potential of shredder fines relies on the integration of both different types of upgrading as well as resource recovery processes. Although such integrated process can be both technically and economically challenging to establish, the methodological approach used for assessing the resource potential of heterogenic residues facilitates a strategic and systematic development of recycling processes. By using this approach, the recycling industry can identify potential recycling options, specify exactly what material constraints that needs to be addressed to comply with current gate and regulatory requirements and develop tailored upgrading and recovery processes for the recovery of multiple resources. Within the project, such potential process schemes were also developed for shredder fines together with different experts from Stena Recycling AB.

**Analyzing the underlying factors influencing current practices**

In Sweden, shredder fines is mainly used as landfill cover material while sometimes it is also landfilled. Why is that so? This study aimed to identify and specific key challenges for facilitating the development of valorisation processes for shredder fines. In doing so, the
underlying policy, market, and organizational factors that sustain the current handling of the material were analyzed through interviews with representatives of different functional areas of a Swedish shredder company. The results show that the current policy and market conditions create strategic incentives for the shredder company to utilize fines for landfill covering, as this practice offers a secure and low-cost outlet that also is regulatory compliant and contributes to the fulfilment of the recycling targets for ELV’s. This practice is also further sustained by that the company perceives strong disincentives for investing in knowledge and technology development for fines valorisation. Unclear and unfavorable regulations for such utilization of waste-based materials as well as a lack of a market demand and user requirements contribute to this situation and make such investments a high risk. Consequently, the anticipated long-term need to eventually change and improve the handling of shredder fines has not yet been prioritized at the corporate level of the company. In practice, this has led to that the handling of fines is in limbo with a lack of organization, assigned resources and capacities to improve the handling of the material.

In sum, this study clearly demonstrates the usefulness of applying a socio-technical perspective on the current management of shredder fines and, by doing so, pinpoint both institutional and organizational factors that need to be addressed to stimulate change and the further development of valorisation options.

**A survey on regulations for controlling the contamination levels in waste**

The design of regulations on the allowable contamination levels in waste to be used has an overarching impact on the possibilities for valorizing shredder fines as well as other similar residues. This study therefore aimed to identify regulatory issues that can be used to control the occurrence of hazardous substances in waste and then analyze how different regulatory responses to these issues affect the conditions for resource circulation. In doing so, we studied how both the circulation and contamination of heterogenic residues, i.e. sewage sludge and waste incineration bottom ash, are regulated in three European countries, and how this in turn has influenced their type and extent of waste utilization. Based on these cases, 8 different regulatory issues that can be asked to control the contamination of waste to be utilized have been identified. The results show that the countries have chosen significantly different responses to these issues, which in turn influence the possibilities for resource circulation for waste producers and users as well as for controlling the dispersal of hazardous substances. Designing these regulations by a risk approach, i.e. the risk of exposure to hazards, is beneficial for short-term circulation and waste producers, while a hazard approach, i.e. the total content of hazards, is beneficial for long-term circulation and waste users. In common for all countries is that the regulations are focused on reducing the dispersal of hazardous substances rather than stimulating resource circulation, and the allowable contamination levels in the waste are typically regulated by its mass rather than what resource utility its utilization provide.

The identified regulatory issues and responses and the analysis of their consequences on resource circulation and dispersal of hazardous substances can be used by policymakers for
designing regulations that balance the conflict between waste utilization and toxicity concerns.

**IMPLICATIONS ON POLICY & PRACTICE**

Although the utilization of shredder fines as a landfill cover material offers a low-cost and regulatory compliant outlet in the short-term, the demand for such cover materials is gradually decreasing in Sweden and will eventually diminish. This long-term need to develop alternatives for the handling of shredder fines that go beyond landfill covering or landfilling is also foreseen by the shredder company, but so far they do not experience strong enough incentives to deviate from disposal and opt for valorisation. In order to initiate such investments in knowledge and technology development for upgrading and resource recovery of shredder fines, the disposal-oriented practice thus needs to be more strongly challenged and favorable and predictable conditions for valorisation of fines established.

Given the technical and economic challenges of valorizing complex materials such as shredder fines, policy and market interventions are essential for increasing the shredder company’s motives for such investments. Through such measures, the current disposal-oriented practice can be challenged by, for instance, revoking the classification of landfill covering (i.e. backfilling) as resource recovery as such utilization currently is exempted from the landfill tax. In order to challenge the disposal-oriented practice even further, this can be followed up by specific landfill bans or higher landfill taxes, thereby increasing the incentives and economic margins for developing alternative management options. However, to not end up in a situation where shredder companies just are penalised with higher disposal costs, such policy interventions need to be complemented with administrative and economic instruments that address the current disincentives to opt for valorisation. By such instruments, a market demand for this type of waste-based resources can be deduced, development consent processes facilitated, and the responsibilities and roles of waste producers and users clarified. Such changes would increase the shredder companies’ confidence in developing different valorisation routes for shredder fines by making it possible for them to foresee the outcome of such investments.

When it comes to the possibilities of valorising shredder fines, and many other similar residues, the design and enforcement of regulations on the allowable contamination levels in the waste to be used are fundamental. It can be concluded that the Swedish approach of using strict guiding values with a focus on total concentrations that are implemented on the local administrative level and without any differentiation between different types of uses has led to an inconsistent enforcement and a low waste utilization rate. As shown in one of the studies of this project, however, there are alternative ways to design and implement such regulations that create more favourable and predictable conditions for resource circulation. The valorisation of shredder fines therefore largely relies on that the current regulations for controlling the contamination in waste are revised – a quest that needs to involve a close
collaboration between the government and industry and specifically target the challenge of how to balance conflicts between resource circulation and dispersal of hazardous substances.

FUTURE OUTLOOK

The PhD-student, Tharaka Gunaratne, that has been working in the project will defend his Licentiate thesis 21 October 2020. He will then continue his PhD-studies on the same topic. More precisely, this work will focus on assessing the potential environmental consequences of implementing the upgrading and resource recovery process schemes that have been developed in this project together with Stena Recycling AB. He will also perform an in-depth study about the market conditions for utilization of such heterogenic residues, specifically targeting key drivers, barriers and challenges related to the (potential) users of such materials.

PUBLICATIONS


The findings from these studies have also been presented at national workshops and seminar, organized by Mistra Closing the Loops II, as well as at several international and scientific conferences (e.g. International Society for Industrial Ecology Conference, Chicago 2017, International Solid Waste Association Conference, Kuala Lumpur 2018 and International Conference on Final Sinks, Vienna 2019).