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Decision making guidelines for mining historic landfill sites in Flanders

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ABSTRACT

This study aims at showing how the United Nations Framework Classification for Resources (UNFC) can help to classify potential landfill mining projects with different levels of maturity, from exploration to production, under technical, socio-economic and project-planning aspects. Taking the example of three former landfill sites in Flanders general decision making guidelines regarding the future management of old landfills are provided. Using the ECLAR methodology for the evaluation (E) and classification (CL) of anthropogenic resources (AR), the individual projects, where clean land and/or materials are recovered, are mapped under the three-dimensional UNFC system. The Bornem project, yields a negative Net Present Value (NPV) of −17 Mio € (−44 €/t of excavated waste), i.e. the project is currently not economically viable. In case of changing key parameters the landfill has, however, reasonable prospects for future economic extraction. The Turnhout land development turned out to be economically viable with a NPV of 361,000 € (8 €/t of excavated waste). The Zuienkerke remediation project is at a too early stage to determine its socioeconomic viability. The main focus to compare and prioritize potential landfill mining projects in Flanders should be on (1) site specific conditions (e.g. landfill's composition, land prices), (2) project related factors (e.g. remediation required vs. resource/land recovery, selected technologies and project set-ups, private vs. public evaluation perspective) and (3) the timing of mining, considering future development of costs, prices, laws, available data and information.

1. Introduction

As an integral part of holistic resource planning strategies, the efficient use of resources, including urban mining, recycling and re-use of waste, has gained increasing importance in Europe (cf. European Commission, 2008). Several studies (e.g. Krook et al., 2012; Kapur and Graedel, 2006; Rettenberger, 2009) conclude that anthropogenic deposits, such as landfills, old buildings and hibernating infrastructure, are comparable in size to the remaining natural stocks of certain metals.

However, up to now there are no comprehensive and systematic concepts to determine the viability of resource extraction, including the value of resources recuperated from waste. To fill this gap and to include secondary raw materials under the United Nations Framework Classification for Resources (UNFC) (UNECE, 2010), a working group on Anthropogenic Resources has been established by the Expert Group on Resource Classification of the UN Economic Commission for Europe (UNECE, 2016). Although UNFC now includes the "Specifications for the application of UNFC for Resources to Anthropogenic Resources", it remains a principle-based system, which still needs to be translated into commodity- and source-specific guidelines. Compared to other resource recovery undertakings, mining resources from obsolete stocks exhibits the most similarities with conventional primary mining projects. In various pilot studies and research projects addressing landfill mining the main goal was to characterize a specific landfill's

Abbreviations and acronyms: CRIRSCO, Committee for Mineral Reserves International Reporting Standards; DCF, Discounted Cash Flow analysis; ECLAR, Evaluation and classification of anthropogenic resources; ELFM, Enhanced Landfill Mining; GHG, Greenhouse gas; KMF, Key Modifying Factors; LFM, Landfill Mining; MFA, Material Flow Analysis; MSW, Municipal Solid Waste; NPV, Net Present Value; OVAM, Public Waste Agency of Flanders; PRMS, Petroleum Resources Management System; RECLAF, Resource Classification Framework for Old Landfills in Flanders; SI, Supplementary Information; SRF, Solid Recovered Fuel; UNECE, United Nations Economic Commission for Europe; UNFC, United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources, since 2017, United Nations Framework Classification for Resources; WtE, Waste to Energy.

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composition and to evaluate its resource potential (e.g. Hogland et al., 2004; Krook et al., 2012; Quaghebeur et al., 2012; Kaartinen et al., 2013; Wagner and Raymond, 2015; Dickinson, 1995; Zhou et al., 2014). Some papers describe suitable technologies for mining, processing and valorization of excavated materials (e.g. Bosmans et al., 2012; Krook et al., 2012; Danthurebandara et al., 2015a).

A number of studies also assess the environmental and economic performance of landfill mining (e.g. Danthurebandara et al., 2015b; Frändegård et al., 2015; Van Passel et al., 2013; Laner et al., 2016; Diener et al., 2015; Winterstetter et al., 2015; Hölzle, 2017; Gäth and Nispel, 2012; Kieckhäfer et al., 2017).

Zhou et al. (2015) are focusing primarily on the economic assessment in their case study for a Chinese landfill, for which different scenarios are investigated. In a cost benefit analysis two alternative land use options are compared, that is, to regain land or to recover landfill space.

Kieckhäfer et al. (2017) provide an economic assessment for a former landfill site in Germany, focusing on the varying complexity and processing effort of the technological alternatives and their effects on the economic and ecological evaluation compared to closure and aftercare. The alternatives range from simple approaches with most of the material being burnt or re-landfilled to sophisticated technology combinations, which allow for recuperating different material fractions, such as metals, plastics, glass, recycling sand, and gravel.

Moreover, various attempts have been made to provide frameworks and/or systematic guidelines to evaluate landfill mining projects. Lederer et al. (2014) came up with a framework to evaluate different types of anthropogenic phosphorus stocks in Austria, using the McKelvey box, an existing primary resource classification framework (McKelvey, 1972). They conclude that for solid waste landfills, which constitute 20% of the anthropogenic Austrian phosphorus stock, mining is by far uneconomical.

Specifically for landfill mining, Hermann et al. (2014) give an overview of relevant economic, ecological, technical, organizational and political factors derived from the 'LAMIS – Landfill Mining Österreich' pilot project in Austria. They also distinguish between a micro (landfill operator) vs. macro (society) perspective, which determines the evaluation's system boundaries and therefore the final result. Based on that, Hermann et al. (2016) designed a comprehensive assessment method including monetary factors but also integrating non-monetary effects, such as the concerns of neighbors or environmental impacts based on a utility analysis. Taking a bottom-up inductive approach, Krüger et al. (2016) derived general guidelines on landfill mining from the research project "TönsLM" in Germany. They recommend to first identify scenarios that are ecologically beneficial and then do an economic assessment (cf. Kieckhäfer et al., 2017). Important factors regarding a project's ecological value include the landfill's gas capture rate, composition, as well as the efficiency of energy recovery plants. Key economic parameters comprise prices for regained land or landfill space and thermal treatment.

Winterstetter et al. (2015) used UNFC to classify recovered materials from the historic REMO landfill site in Belgium and developed a first operative evaluation procedure including classification criteria, which was also applied by Krüse (2015) to the Hechingen landfill in Germany.

To facilitate the classification of further kinds of anthropogenic resources and compare, for instance, extracted materials from historic landfills to e-waste recycling, the ECLAR methodology for the evaluation (E) and classification (CL) of anthropogenic resources was developed (Winterstetter, 2016).

The Public Waste Agency of Flanders (OVAM) – in charge of preparing waste and soil policies - developed the FLAMINCO model (Flanders Landfill Mining, Challenges and Opportunities) as a screening tool, based on a multi-criteria analysis (Behets et al., 2013) to assess the contamination risks and respective resource potential of old landfills. Based on this work, OVAM is currently prospecting the resource and land recovery potential of further selected historic landfills. For this purpose old landfills are continuously inventoried and integrated with the spatial model of Flanders. The goal is to systematically provide information for the future management of 2000 historic landfills, out of which the majority is no longer operational (Nagels and Wille, 2017).

While the studies mentioned above have made valuable contributions towards the classification of potential landfill mining projects, they are very focused on the details of specific case studies. Their bottom-up derivations of general landfill mining guidelines from specific cases are usually justified with extensive sensitivity analyses.

The novelty of this study is to compare different potential "real-life" landfill mining projects in Flanders and their specific settings. Such a comparative approach is necessary to identify those landfills where mining could already be economically viable. It also helps to decide and prioritize which detailed further investigations are necessary to have a solid foundation for decision making. For instance, in some cases assessing the exact aftercare period and the associated costs is of high relevance, whereas for other landfill sites it might be more worthwhile to investigate their land development potential.

In the densely populated Flemish region the need for new clean land, including the value of land, are the key drivers fueling interest in landfill mining, while the value of extractable materials or environmental benefits play only a secondary role.

This present study derives the guidelines on the future management of landfills in Flanders top-down from UNFC, a resource classification framework that has been developed in the mining industry.

So, the goal of this paper is to show how the United Nations Framework Classification for Resources (UNFC) can help to classify potential landfill mining projects with different levels of maturity from exploration to production, based on three landfill sites in Flanders (portfolio management). Further, this study aims at providing decision making guidelines regarding the future management of old landfills in line with UNFC considering technical, socio-economic and project-planning aspects, to decide whether a landfill site is to be mined or not, and under which framework conditions.

2. Materials and methods

2.1. Operative evaluation procedure

To facilitate the integration of anthropogenic resources into the United Nations Framework Classification for Resources (UNFC), which was originally designed for primary resources, the ECLAR methodology for the Evaluation (E) and Classification (CL) of Anthropogenic resources (AR) was developed (cf. Supplementary Information SI, chapter 4 & 5). It comprises an operative evaluation procedure as well as a set of specifications to classify recovered resources from old landfills and other types of anthropogenic deposits (Winterstetter, 2016).

The evaluation is built on a spreadsheet tool that allows also analyzing the effect of changes in various conditions (e.g. land prices, metal prices, sorting efficiencies) on the economics of a landfill mining project. To decide whether to start actual mining activities or not, the stages '(pre-) prospection', 'exploration' and 'evaluation' have to be run through. After screening existing data bases and selecting a specific deposit for potential mining, three key aspects – as used under the three dimensions of UNFC - need to be considered (cf. Table 1).

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