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Urban infrastructure mines: on the economic and environmental motives of cable recovery from subsurface power grids

Joakim Krook*, Niclas Svensson, Björn Wallsten

Department of Management and Engineering, Environmental Technology and Management, Linköping University, SE-581 83 Linköping, Sweden

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A B S T R A C T

Subsurface power grids constitute one of the largest copper stocks in many industrialized cities. Over time, parts and zones of these systems have been continuously disconnected and abandoned, resulting in the emergence of urban infrastructure ores. This study aims to assess how current conditions and practices influence economic and environmental motives of cable recovery from such power grids. By applying an infrastructure manager's perspective and evaluating 16 scenarios involving different extraction technologies and procedures, surface materials, urban locations and types of cables, we identify key areas where solutions or changes to increase incentives for cable recovery are needed.

The assessed scenarios display significantly different cable extraction costs, where excavation in city centers with asphalt or cobblestone pavements generates the highest costs while greenbelts offer the best conditions. In most cases, cable revenues are not even close to outweighing the extraction costs. This is especially true for paper-coated cables or cables with aluminum conductors, for which the revenues are much lower than for plastic-insulated copper cables. Although economic conditions could be improved by integrating cable recovery to regular system upgrade projects or by applying non-digging technologies, clear incentives rely on the cable in question being especially valuable. Most of the cable recovery scenarios display environmental motives in terms of net savings in GHG emissions due to metal recycling. In contrast to the economic results, recycling of aluminum power cables is here more awarding than that of corresponding copper cables.

We conclude that under current conditions urban mining does not make economic sense to infrastructure managers unless it is integrated as an added value to system upgrade projects. Apart from such re-arrangements in infrastructure provision, several other practice-related changes to cut cable extraction costs are possibly within reach for the managers. Still, an economically motivated practice relies on several external performance drivers such as market diffusion of non-digging technologies, improved cable recycling processes, and increased scrap metal prices. Our conclusion that the arguments for urban mining are currently more environmental than financial, points towards changed perspectives where such activities are seen as a way for infrastructure managers to contribute to societal goals such as climate change mitigation and reduced mineral resource dependence.

1. Introduction

A key challenge of sustainability is that mankind has to increasingly rely on recycling of materials, not only for environmental reasons but for the political and economic implications of universal changes such as primary resource scarcity as well. From a mass flow perspective, such a challenge is inherently problematic given that the annual societal discards often are too small to cover any significant share of our steadily increasing appetite for natural resources (Baccini and Brunner, 2012). On the other hand, when it comes to strategically important base metals almost half of the amounts extracted to date are no longer in use (Spatari et al., 2005; Müller et al., 2006). These previously employed materials can be found either in different waste deposits or in obsolete products, buildings and infrastructure left behind in the built environment. Exploiting these often forgotten technospheric stocks, sometimes referred to as urban and landfill mining, could thus provide the recycling industry with significant amounts of additional raw materials, making it possible for this sector to grow beyond the physical limits of annual waste streams and become a more

* Corresponding author. Tel.: +46 13 28 89 03; fax: +46 13 281399.
E-mail address: joakim.krook@liu.se (J. Krook).

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important supplier (Bergbäck and Lohm, 1997; Krook et al., 2011, 2012).

In Sweden, it has been estimated that the amount of accumulated copper in power and telecom grids exceeds 1.5 million metric tons, making such infrastructure one of the largest stocks in the technosphere (Wendell, 2005; Sörme et al., 2001; Krook and Baas, 2013). The majority of these quantities of copper are located in urban areas – a phenomenon which is also confirmed by international studies demonstrating concentrations of metal up to a hundred times higher in urban than in rural areas (van Beers and Graedel, 2007). One contributing factor to this high density in metal stocks is that subsurface infrastructures for power, telecom, gas, water supply and so on consist of massive networks of cables and pipes rich in base metals such as iron, copper and aluminum (Wendell, 2005; Wallsten et al., 2013a). Such infrastructure systems permeate industrialized cities in the northern hemisphere, and as such are literally embedded in the urban fabric (Graham, 2000). While most of this infrastructure is still operational, parts and zones of these networks have been continuously disconnected during maintenance and system upgrading and thereafter left behind in the "invisible" urban landscape. Over the decades, this disconnect-and-leave-behind logic of infrastructure provision has resulted in the accumulation of significant subsurface urban ores – obsolete metal stocks accessible for urban mining initiatives (Krook and Baas, 2013).

Many of the still operational, first-generation infrastructure networks are old and have already surpassed their lifetime expectancy. In order to secure their essential functions, huge investments in replacements and system upgrading will be required in the years to come. Knowing that the very limited urban infrastructure mining that currently occurs only does so in relation to system maintenance and repair (Wallsten et al., 2013b), suggests a potential for integrating urban mining initiatives with such future system upgrades.

So far, urban mining research on disconnected subsurface infrastructure has mainly focused on analyzing the occurrence, quantities and spatial location of metals stocks (Krook et al., 2011; Wallsten et al., 2013a). Although it is concluded that the established disconnect-and-leave-behind logic originates from a combination of technical, organizational, cultural and regulatory conditions (Wallsten et al., 2013b), the most straightforward reason for why derelict cables remain in the soil is the high costs for urban excavation work (Krook et al., 2011). However, the economics of such urban mining projects have not yet been thoroughly studied and are thus largely uncertain. In fact, there are many economic aspects that may or may not turn out to be significant depending on exactly where, how and for what reasons projects are realized. In principle, the same is true for the environmental impacts of this type of urban mining where the type of cable(s) to be extracted, street paving, applied technologies, procedures for site restoration, accessible markets for recycling and transportation needs are all examples of potentially influencing factors. Identifying the potential and challenges related to urban infrastructure mining thus calls for a system approach reliant on a wide range of project-specific factors and the inclusion of both economic and environmental motives.

1.1. Aim

The aim of this article is to assess how current technical, organizational, regulatory and market conditions and practices influence economic and environmental motives of cable recovery from disconnected urban power grids in Sweden. This is engaged with in order to illuminate under what site-specific factors and in which project settings urban mining might be a potentially economically viable activity for the individual actor as well as environmentally justified for society at large. Rather than drawing conclusions about the net economic and environmental performance of specific urban mining projects, our intention here is to learn more about the relative importance of different influencing factors and conditions and thereby pinpoint key topics for future knowledge, technology development or societal rearrangements.

2. Analytical approach and method

This article applies an actor perspective, implying that the focus is on the acting space of actors involved in the process of inquiry while the external framework (i.e. current policy, regulatory and market conditions) in which the actors' activities take place is assumed to remain unaltered. Our emphasis is thus to break down the current economic and environmental (dis-)incentives of urban mining for the local infrastructure manager, rather than assessing impacts of different external changes in waste management and recycling markets, raw material prices and national policies regarding, e.g., resource conservation or infrastructure regulation. The plain argument for choosing such an actor's point of view is that urban mining will most likely not happen if it cannot be economically or environmentally motivated for the local infrastructure manager.

This article is an urban mining case-study of the city of Linköping.[1] Our approach is to assess the heterogeneous complexity found in the details of this specific case as a way to initiate knowledge and theory development within this emerging area. This means that the results are primarily applicable to the studied case, but the fact that infrastructure provision is arranged in the same way in many other domestic cities (EBR, 2013) implies the relevance and generalizability to Swedish conditions and practices. Although the overall findings from this case-study plausibly also are of relevance for urban infrastructure mining in other cities throughout the world, we believe that any such generalization must go with a thorough analysis of the actual conditions and practices of the specific case in question. Thus, in order to accurately extend the generalizability of our results beyond Swedish boarders and conditions, comparative studies from other parts of the world are strongly encouraged.

2.1. Developing scenarios for evaluation of urban infrastructure mining

In both the economic and environmental assessment, our ambition has been to define cable extraction scenarios describing the best as well as worst-case scenarios. This enables us to display interval ranges in which possible real-world projects can be located as well as compared. To these intervals, representing different cost and environmental impact profiles, we add break-even lines indicating revenues and avoided environmental burdens that are obtained by recycling different power cables. Such an analytical approach makes it possible to identify and discuss changes required for a project to make either economic or environmental sense.

2.1.1. Main variables influencing costs and environmental impacts of cable extraction

Even if an urban infrastructure mining project is limited both in time and space, it can nevertheless be done in many different ways. To encapsulate this diversity, the study was performed through the development of 16 cable extraction scenarios that rely on four sets of main variables: extraction technology, geographic location, type

[1] Linköping is a medium-size Swedish city with approximately 140,000 inhabitants.