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The institutional capacity for a resource transition—A critical review of Swedish governmental commissions on landfill mining

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A B S T R A C T

Recycling of minerals from waste deposits could potentially double the recycling flows while offering an opportunity to address the many problematic landfills. However, this type of activity, i.e., landfill mining, brings many advantages, risks and uncertainties and lacks economic feasibility. Therefore, we investigate the capacity of the Swedish authorities to navigate the environmental, resource, and economic conditions of landfill mining and their attitude to support such radical recycling alternatives towards a resource transition.

By analyzing three governmental commissions on landfill mining, we show how the authorities seem unable to embrace the complexity of the concept. When landfill mining is framed as a remediation activity the authorities are positive in support, but when it is framed as a mining activity the authorities are negative. Landfill mining is evaluated based on how conventional practices work, with one and only one purpose: to extract resources or remediation. That traditional mining was a starting point in the evaluation becomes particularly obvious when the resource potential shall be evaluated. The resource potential of landfills is assessed based on metals with a high occurrence in the bedrock. If the potential instead had been based on metals with low incidence in the Swedish bedrock, the potential would have been found in the human built environment.

Secondary resources in landfills seem to lack an institutional affiliation, since the institutional arrangements that are responsible for landfills primarily perceive them as pollution, while the institutions responsible for resources, on the other hand, assume them to be found in the bedrock. Finally, we suggest how the institutional capacity for a resource transition can increase by the introduction of a broader approach when evaluating emerging alternatives and a new institutional order.

1. Introduction

The minerals found in today's applications come mainly from the Earth's crust. The social and ecological consequences of extracting these minerals are severe (UNEP, 2013). Therefore, a transition of the resource sector towards a predominant use of waste as the main source of resources in the economy has been politically proposed (cf. European Commission, 2015). However, the waste streams are too small to cover a significant share of the increasing demand on resources. At the same time, the recycling rate of many base metals such as steel, copper, lead and aluminum is already high in countries with developed waste management systems and cannot increase significantly (UNEP, 2011).

One way to increase recycling would be to focus on a type of mineral stock that is often forgotten in discussions about resource availability (cf. European Commission, 2008; USGS, 2015), namely those excluded from the anthropogenic flows and over time accumulated in different waste deposits (Ayres, 1997). Some researchers claim that waste deposits are bursting with resources, i.e., globally the amount of copper is comparable to the current in-use stock (Kapur, 2006). At the same time, many landfills pose risks to the environment and health. The strategy of extracting disposed resources combined with remediation measures of landfills, i.e., landfill mining, could thus be a strategy to handle the many problematic landfills, while potentially avoiding primary production.

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Like other sustainability-driven transitions, a *resource transition*, i.e., the transition towards dominant use of secondary resources brings not only benefits but also numerous problems, uncertainties, and negative aspects. Recycling of disposed materials can partly substitute for primary production, thereby mitigating its consequences, but may at the same time cause other socio-ecological implications such as impacts and risks related to the landfill excavation. Furthermore, a major obstacle to recover minerals from unconventional stocks such as landfills is the lack of economic feasibility, as the costs typically exceed revenues (Van Passel et al., 2013; Frändegård et al., 2015). This environmental ambivalence and lack of economic turnover is common in most emerging environmentally driven niches such as wind turbines (e.g. Leung and Yang, 2012), organic food production (DeLonge et al., 2016) and biofuels (Tenenbaum, 2008; Levidow & Papaioannou, 2013).

However, the lack of profitability depends partly on a market situation where policies and economic frame conditions are adapted to conventional methods of agriculture, energy (IEA, 2016), and in this case, mineral production (Johansson et al., 2014). As environmentally driven transitions rarely bring an explicit market advantage, neither to the user in terms of lower price and higher performance nor for the company due to lack of profitability and lower returns, their success has typically depended on political intervention through, for example, various types of policy instruments. For example, the market share of biofuels has increased thanks to subsidies (cf. IEA, 2016), which have demonstrated an openness to different types of fuels: ethanol, biogas, hydrogen and electric vehicles.

The government support of the emerging alternatives, however, puts demands on capacity to navigate among the environmental benefits, risks, and uncertainties from such activities. To realize the potential of landfills and strive towards a resource transition, many researchers and industrial actors have proposed favorable policy changes to increase recycling (Van Passel et al., 2013; Johansson et al., 2014; Schelin, 2014). The governmental attitude towards innovative resource operations targeting novel mineral stocks such as landfills is, however, still unclear, as is how they navigate its pros and cons.

Sweden is one of the countries where landfill mining has received widespread attention and is mentioned for example in the national waste plan by the Swedish Environmental Protection Agency (SEPA, 2012). As a consequence, the Swedish government has formed commissions to investigate the potential and opportunities to support recycling of deposited waste (SEPA 2013, 2015; SGU, 2014). These reports open up opportunities to analyze how governmental agencies evaluate and make sense of landfill mining. This is in a country where the mineral policy has by tradition been adapted for minerals to be mined from the Earth's crust (Johansson et al., 2014).

The aim of this paper is to assess the governmental ability and capacity to evaluate landfill mining. With this background the following research questions can be formulated: how do Swedish governmental agencies navigate the advantages, disadvantages, and uncertainties of landfill mining? What is the institutional capacity of the Swedish government to evaluate emerging recycling alternatives? Institutional capacity should be understood as the ability of public institutions to manage, solve problems, and achieve goals in relation to increased secondary resource extraction.

2. Landfill mining: resource, environmental and economic aspects

The research on landfills as mines has so far been engineering-oriented with a focus on three main aspects: the resource potential, economic feasibility, and environmental impact of recovery operations as seen in Table 1. These aspects have been examined either by implementing small-scale pilot studies, material flow analyses or assessments of full-scale mining operations. Successful large-scale recycling projects are rare, but there are exceptions (e.g. Wagner and Raymond, 2015).

2.1. The resource potential

A review of the literature indicates that landfills hold great resource potential, but that it can be difficult to utilize. About half of the excavated base metals from the Earth's crust such as copper have accumulated in various types of waste deposits such as landfills, tailings, and slag heaps (Kapur, 2006). The advantage of extracting minerals from waste deposits is that they are gathered in a confined place and are immediately available. The concentration of minerals in some waste deposits, such as 2% copper in a shredder landfill in southern Sweden (Alm et al., 2006) are far higher than in active copper mines, which are on average 0.8% (Crawson, 2012), but lower than in a mobile phone.

Landfills are, however, just like mines finite stocks of minerals, and will deplete if landfilling of minerals stops. Some waste deposits and in particular municipal landfills have unfavorable conditions for resource extraction, such as a heterogeneous and humid content (Johansson et al., 2016). Furthermore, the quality of the material in landfills deteriorates over time due to oxidization and biodegradation (USEPA, 1997). There are also no reliable technologies for sorting disposed waste with high efficiency and

Table 1
Resource, environmental and economic aspects of landfill mining found in the scientific literature is presented according to advantages and disadvantages. Aspects marked with (*) are potential indirect consequences of landfill mining.

	Advantages	Disadvantages
Resource	+ In total, significant amounts of minerals	– Lack of sufficient technologies
	+ Directly available	– Heterogeneous material
	+ High mineral concentration	– A finite mineral stock
	+ Minerals confined in one place	– Declining quality over time
		– Some landfills are relatively small
Environment	+ Metal recycling avoids CO_2 emissions*	– Burning of plastic increases CO_2 emissions*
	+ Avoids methane emissions*	– Increased noise, odor and transport
	+ Remediation and management of hazardous waste	– Risk of leakage, landslides and collapse
	+ Upgrade the landfill construction according to existing safety standards	– Health risks for workers
	+ After treatment and reduced leaching*	– Local residents' concerns
Economy	+ Positive community effects, e.g., work opportunities	– Costs higher than revenues
	+ Increased self-sufficiency of minerals*	– Metals are the only fraction that generates an income
	+ The cost of remediation can decrease	– Regulatory barriers such as landfill bans and taxes
	+ The land can be reclaimed into parks or housing	
	+ Additional landfill space could be created	

prospecting waste deposits to identify exactly where the valuable minerals are located (USEPA, 1997). Hence, extracting resources of high quality is a significant technical challenge and the main focus of landfill mining research. Compared with traditional mines, the total amount of minerals in all landfills as well as in individual landfills is relatively small.

2.2. Environmental impact

It is generally recognized that extracting resources from landfills could generate significant global environmental benefits such as energy savings (Frändegård et al., 2013; Jones et al., 2013), based on the assumption that recycling will replace mining operations. Energy recovery of combustibles from landfills may also replace conventional energy generation, which in many parts of the world is still fossil-based. However, some studies demonstrate moderate climate savings from recycling deposited waste (Winterstetter et al., 2015), and sometimes even negative results (Laner et al., 2016). The environmental impacts seem to depend on site-specific conditions such as material content in relation to regional aspects such as the system for electricity production. For example, no gas collection or high content of aluminum in the landfill is favorable while a high proportion of plastic or rubber intended for energy recovery in a region with renewable energy leads to net emissions (Laner et al., 2016).

Local environmental consequences of landfill mining have been less investigated. Most of the local impacts and risks associated with the disposal of waste seem, nevertheless, to revive when the material flow turns and disposed waste is exhumed to the surface, such as transportation, noise, landslides, collapse, smell, risk of infection, dust, fire, health and safety risks, and leakage of metals and other impurities (USEPA, 1997). There is a general risk when the landfill is opened up that the emissions that normally seep out slowly instead overflow during an intense period. Remediation of landfills has also shown that excavations of landfills can create local protests and concerns (Johansson et al., 2012). To exhume and sort waste means, however, that the very source of the risks (hazardous waste and other material discharging emissions) can be addressed (USEPA, 1997). In addition, possibilities are opened up to secure the landfill by, for example, bottom sealing, installing drainage or gas collection systems (Cossu et al., 1996).

2.3. Economic impact

Most hypothetical studies demonstrate that the costs of excavation, sorting, and treatment of hazardous waste exceeds the anticipated revenues for extracted materials (Van Passel et al., 2013; Frändegård et al., 2015). The waste market is constructed in such a way that metals are usually the only profitable fraction, while for example energy recovery in most waste markets involves high gate fees. In cases when further revenues can be included in the form, for example, of the value of reclaimed land, increased landfill space or the alternative costs of leaving the landfill as is, the recycling operation has demonstrated a profit (Johansson et al., 2012; Wagner and Raymond, 2015). Like virtually all industrial activities, large-scale mining operations could strengthen local economies by offering job opportunities with related spillovers upstream and downstream to the clean tech sector. By increasing the recycling flows, the need to import minerals can decrease, thus achieving geopolitical advantage (Jones et al., 2013).

The general negative financial results depend partly on poor quality of the waste and lack of appropriate separation technology, but also on unfavorable institutional conditions for landfill mining. The regulatory framework surrounding landfills is adapted according to a perception of landfills as a material end station rather than a starting point (Johansson et al., 2012). This means that the institutional conditions for landfills are designed primarily to avoid or keep the waste in landfills. For example, the landfill tax, designed to reduce the rate of landfilling, could lead to significant costs in a landfill mining project, about 30–50% of the total costs (Frändegård et al., 2015). At the same time, due to bans on landfilling organic waste and combustibles, re-deposition could be illegal (Johansson et al., 2016).

3. Method

To understand how the Swedish authorities make sense of landfill mining, we looked closely at three different government commissions, Table 2. These commissions have involved three different agencies over a three-year period (2013–2015). SEPA was responsible for the first and third commission, while the Swedish Geological Survey (SGU) was responsible for the second commission. In addition, the Swedish Tax Agency assisted SEPA in the first and third commission, while SEPA assisted SGU in the second commission. SEPA was established in 1967 with the target as the spelled-out name suggests to protect nature mainly by natural conservation measures driven by many biologists and ecologists. SGU was formed in 1858 and has since then been responsible for the Swedish geological and mineral processing issues, naturally with strong links to the field of geology.

Government commissions generally have a decisive influence on Swedish policy and aim to prepare, examine, and formulate new policies on specific policy issues. Or as Hesslen (1927: 6, referenced from Hysing and Lundberg, 2016 puts it: commissions are “temporarily appointed to handle specific policy issues, whose findings shall serve as the basis for a government decision.” Government commissions normally include experts, business, and NGOs.

The first report, *Review of the landfill tax* (SEPA, 2013), examines all the exemptions from the landfill tax, and includes an extended analysis of the effect of exempting residues of a landfill mining operation from the landfill tax. One of the conclusions of this report is that the effects of exempting the tax for landfill mining needs further analysis, which is the background to Report 3, *Recycling of waste facilities* (SEPA, 2015). Report 2, *Analysis of the recovery potential* (SGU, 2014), derives from the Swedish mineral strategy (Swedish Government, 2013) where it is stated that the domestic recovery potential of mining and recycling shall be mapped. Report 3, unlike the other reports, is exclusively about landfill mining, but only targeting closed landfills. All reports are

Table 2
An overview of the reports analyzed in this study.

Governmental commission	Year	Objective	Responsible authority	Participating authority
1. Review of the landfill tax	2013	Reviewing the landfill tax. Assessing fiscal and environmental effects of landfill mining	SEPA	Tax Agency
2. Analysis of the recovery potential	2014	Identify and analyze the extractive and recycling potential for mineral resources in Sweden, above and below ground	SGU	SEPA
3. Recycling of waste facilities	2015	If appropriate, suggests policies that favor remediation and recovery of materials from closed landfills.	SEPA	Tax Agency

written in Swedish. All the quotes in this paper have been translated by the authors into English. It should also be mentioned that the authors have been partially involved in producing background material for the governmental commissions. Thus, there is a risk that we analyze our own perceptions and positions, but at the same time, our contribution has been limited and consistently represented only a small part of the reports.

3.1. Analysis

To understand what the text tells us, or more precisely how the government makes sense of landfill mining, the reports have been thematically categorized (cf. Bowen, 2009). Themes were developed by a deductive review of scientific literature with specific focus on advantages and disadvantages of landfill mining, which is presented in Chapter 2, Table 1. This process, however, has been iterative, as categories have been constructed based on both the literature review and the content of the actual reports. The themes that emerged from this process are: *Resource, Environment* and *Economy*, according to which the three reports were coded. These themes were then analyzed with the inspiration of frame analysis, where the authorities' position on landfill mining was analyzed as a result of *inclusion* and *exclusion mechanisms* (cf. Goffman, 1974), in which some aspects are highlighted while other aspects are denied space, which leads to a conclusion on support.

The advantages and disadvantages of landfill mining as presented in Chapter 2 are used as a backdrop for analyzing which of these pros and cons the authorities emphasize in their arguments on the resource, environmental, and economic potential of landfill mining. But pros and cons in relation to the themes that are not mentioned in the report are also partly included in the discussion. By excluding and including certain aspects of a phenomenon, in this case landfill mining, it becomes framed and defined in a particular way, which legitimizes a proposed policy direction (cf. Weiss, 1989). To frame, according to Entman (1993), "is to select some aspects of a perceived reality and make them more salient in a communicating text, in such a way as to promote a particular problem definition, causal interpretation, moral evaluation, and/or treatment recommendation for the item described." Based on how the authorities include and exclude certain aspects, we will discuss the institutional capacity to evaluate emerging recycling alternatives towards a resource transition.

4. Result: the authorities' perspectives on the resource, environmental and economic potential of landfill mining

The three governmental reports are in sum ambivalent towards supporting landfill mining. The first two reports are positive about changing the institutional conditions for landfill mining, as the SEPA (2013: 92) argues that "there are [. . .] reasons to provide incentives for landfill mining" by for example "exempting taxes for residues from landfill mining operations." SGU (2014: 4) concludes that "the potential of secondary resources will not materialize by itself [. . .] therefore, new or changed instruments are needed." In the latest report from the SEPA, however, the attitude to landfill mining has changed and the SEPA (2015: 8; 36) believes that there "is currently not enough reason for the state to promote landfill mining." The reasons for the different standpoints expressed in the reports depend largely on the perspective of each report, Fig. 1, and the inclusion and exclusion of aspects as will be presented below.

4.1. Resource potential

In the first report, the SEPA (2013: 91) is positive about the resource potential in municipal landfills and mentions that "the amount of deposited metals in the Swedish municipal landfills is equivalent to five years of metal consumption in Sweden" with a value of "between 50 and 75 SEK billion." In addition, the SEPA recognizes (2013: 91) that there is a large amount of combustibles in Swedish municipal landfills "corresponding to 260–350 TWh of heat and 30–40 TWh of electricity." In the third report, however, the attitude of the SEPA (2015: 7) towards the resource potential of Swedish landfills changed and became negative: "The potential is modest compared to the mining potential." To exemplify the poor resource potential, the SEPA (2015: 43) shows that the concentration of iron in the "Kiruna mine," the world's largest underground mine, is about seven times higher than in a typical municipal landfill. Furthermore, according the SEPA, the Kiruna mine produces annually five to six times more iron (25–30 million tonnes) than the estimated total amount of extractable iron in all Swedish municipal landfills (five million tonnes).

The background to the SEPA's changed perception of the resource potential is that between these two reports, in partnership with SGU (2014) they mapped the total metal potential for recycling and mining, Report 2. An overall conclusion from this report is that "the greatest potential of minerals is found in

REPORT		RESOURCE	ENVIRONMENT	ECONOMY	SUPPORT
1	Review of the landfill tax	+ Great potential	+ Avoids CO2 + Remediation + After treatment	+ Reduces costs for remediation	Reasons for incentives (thumbs up)
2	Analysis of the recovery potential	- Limited compared to mines	n.a.	n.a.	New instruments are necessary (thumbs up)
3	Recycling from waste facilities	- Limited compared to mines	- Risk of leakage - Uncertain impact	- Costs higher than revenues	Not enough reasons for support (thumbs down)

n.a.= not available

Fig. 1. The attitudes towards support of landfill mining, based on the expressed environmental, resource, and economic pros and cons of landfill mining in the three reports.

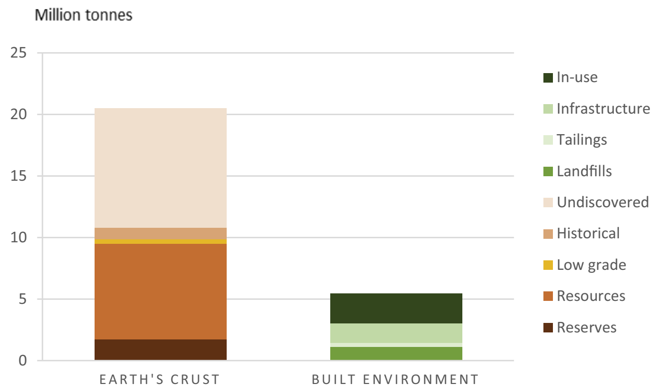

Fig. 2. The resource potential of copper in the Earth's crust compared to the built environment. The occurrence of copper in the built environment is divided into different copper stocks, while the occurrence in the Earth's crust is presented according to the resource classification of References: SGU (2014); UNEP (2010).

theSwedish bedrock" (SGU, 2014: 4). For example, according to SGU (2014: 41) the recovery potential of iron, copper, lead and zinc is 5–20 times higher in the Swedish bedrock than in the built environment accessible for recycling, see Fig. 2. SGU (2014:4) emphasizes that the potential for recycling is uncertain; there are clear guidelines for assessment of the potential in the bedrock, but "the assessment of secondary resources is theoretically calculated and therefore indicative only." These uncertainties could be the reason why SGU (2014:38) reports a higher secondary resource potential in landfills than the SEPA (2015) by including the total amount of scrap iron in landfills, which is three times higher (13 million tonnes) then SEPA's estimation of the extractable potential.

4.2. Environmental potential

In the first report, landfill mining is presented by the SEPA (2013: 85) as an innovative form of remediation to manage the Swedish landfills "lacking sufficient top and bottom sealing or leachate treatment" that pose a risk to environment and health. If requirements are placed on landfill mining operations to "after treat and remediate the landfill" (SEPA, 2013: 90), the local, regional and global environmental impacts from landfills could be reduced. Moreover, material and energy recovery are believed to generate additional benefits to a remediation project, since many of the environmental impacts related to primary production could partly be avoided. This makes the environmental gains of remediation where masses are only moved to a safer place "significantly lower compared to integrated remediation and landfill mining" according to the SEPA (2013: 88).

In the third report, the starting point is that landfills are excavated for resource needs rather than remediation. Since the resource potential in landfills in this report is presented as negligible, the SEPA (2015: 9) argues that "the recovery from closed landfills has an insignificant impact on the extraction of virgin resources and thus also the emissions from mining operations." At the same time, "the extent of the environmental benefits are uncertain [from landfill mining] because the landfill location, content and status varies from case to case" (p. 29). The resource perspective also means that the focus shifts from how landfill mining can address environmental problems in the first report to potential local risks of landfill mining and "the spread of unwanted substances, gases, noise and smell" (p. 30). The second report (SGU, 2014) and the mapping of the mining and recycling potential lack an environmental perspective.

4.3. Economic potential

In the first report, in which landfill mining is assumed to be integrated with remediation, the SEPA (2013: 91) argues that recycling "could be a way to finance/co-finance remediation of closed municipal landfills." Landfill mining is thus regarded as an opportunity to reduce the high costs of remediation projects, a cost that in some cases is taken from the public treasury. Residues from landfill mining operation should according to the SEPA (2013: 91) be exempt from the landfill tax as "waste from landfill mining should legally be handled in the same way as contaminated soil from remediation," masses that are exempt from the tax.

In the third report, where landfill mining is driven for resource concerns rather than remediation, the SEPA (2015: 26) argues that landfill mining should be a project that "becomes profitable from a business perspective." This type of innovative resource extraction is no longer regarded as primarily an environmental measure, but rather it is traditional business: "The market for landfill mining has the same drivers as the free market for other goods, i.e., if the market price of resources in a closed landfill is high enough, landfill mining will happen" (p. 32). Consequently, there is no interest to support innovative recycling operations: "for the Government to support landfill mining, there needs to be commercially interesting closed landfills" (p. 33). SEPA believes, in other words, that support can be envisaged only when these recycling projects already are marketable, rather than perceiving support as a form of push to help an emerging business become competitive in the market. Moreover, the Tax Agency parallels residues from landfill mining operations with residues from conventional recycling, which is subject to the tax (p. 48). Thereby, they become negative to exempting residual fractions of landfill mining from the landfill tax. In the second report, where SGU (2014) maps the extractive and recycling potential, an economic perspective on the resource potential is lacking.

5. Discussion: the framing of disposed material

The Swedish authorities deal with the concept of landfill mining by establishing "conceptual hooks" (Zucker, 1991) and compare it with known phenomena with which they have experience, in this case, remediation or mining.

5.1. Framing the economic potential

When landfill mining is compared with remediation in the first report, i.e., in the *pollution frame*, it is presented as a better alternative than the latter due to the possibilities of economic revenues from material sales and avoided environmental emissions from recycling, which leads to a logic that landfill mining should be supported. But on the other hand, when landfill mining is compared to traditional mining in the third report, i.e., in the *resource frame*, the latter is considered to be a better option due to the limited resource potential in landfills accompanying negligible environmental benefits, which leads to a logic that landfill mining should not be supported.

The framing of landfill mining as a method of remediation or resource extraction seems to be based on how deposited waste should ontologically be understood: as a source of pollution or resources, respectively. The SEPA (2013) shows an openness to support recycling schemes when the disposed waste is framed as a pollutant (remediation) rather than a resource (mining). Thus, defining waste as a resource does not appears to be advantageous. When the material is understood as a pollutant, as "bads" (Thompson, 1979), there is a willingness to pay as much as necessary to get rid of it. But when the material instead is framed as a resource, as "goods" (Thompson, 1979), the value of the material has to cover the cost of all the processes (exhuming and separation). According the SEPA (2015), operations targeting resources shall work on the free market and support is therefore not legitimate. For example, landfill mining operators should pay landfill tax. However, this conclusion comes from paralleling landfill mining with conventional recycling in the third report. If the SEPA instead had contrasted the tax situation with traditional mining, exempting the tax from landfill mining would have been reasonable since this is the case for traditional mining.

Disposed waste, however, is not necessarily a pollutant or a resource, since a landfill may contain both valuable resources such as metals and pollutants in the form of asbestos. Moreover, the same material such as copper or lead may be a resource and a source of pollution at the same time, if it holds a high market value but leaches into the environment. To exhume a landfill in order to recover resources and take care of hazardous waste can therefore be a combined strategy of remediation and resource extraction, and not necessarily a choice between these two activities. Landfill mining may also bring other gains such as land reclamation or creating space for deposition and thereby avoiding new landfills (Johansson et al., 2012).

This complexity with multiple objectives seems to characterize emerging environmentally driven alternatives. For example, biofuels are so much more than just a vehicle fuel (cf. Wright and Reid, 2011), as they can also serve as a way to manage waste, strengthen local economies, and promote energy independence. However, the authorities have difficulties in embracing this complexity, at least in the case of emerging recycling initiatives. In the first report, landfill mining is contrasted to remediation activities. Although the presence of resources is estimated, it is never further evaluated in depth. In the third report, landfill mining is contrasted to conventional mining, while remediation is only mentioned in passing and not further evaluated. When landfill mining is evaluated it is thus based on how conventional practices work with one and only one purpose: to remediate (Report 1) or extract resources (Report 3).

5.2. Framing the resource potential

The SEPA's comparison of the resource potential in landfills with mines, and in particular the world's biggest underground mine in the third report, demonstrates how traditional large-scale modes of production serve as a starting point in their evolution of the alternatives. This is since *one* mode of production is assumed to replace the dominant mode of production. However, the emerging alternatives are typically characterized by a number of smaller forms of production, where landfills are only one of several mineral stocks of secondary resources potentially available for extraction (see Johansson et al., 2013). Similarly, using biofuels as an example again, a variety of alternative fuels, in the form of, for example, biogas, ethanol, solar, electric and hydrogen, may replace the dominant petroleum-based fuel. Any of these alternatives alone would be categorized as having low potential.

Even when the authorities (SGU, 2014) aim to evaluate the resource potential in the whole human built environment, Report 2, the evaluation is still insufficient. Only two different types of waste deposits are included: municipal landfills and tailings, see Fig. 2. Other waste deposits in the form of, for example, gangues, industrial and foundry landfills are excluded. However, above all, the comparison in Reports 2 and 3 between the recycling potential and the mining potential is based on the metals (iron, copper, lead and zinc) that have a high presence in the Swedish bedrock. If the comparison in Reports 2 and 3 had instead been based on another metal with low incidence, such as aluminum, the result of the comparison would reverse since Sweden has no bauxite-rich bedrock according to SGU (2014), see Fig. 3. In addition, if such a

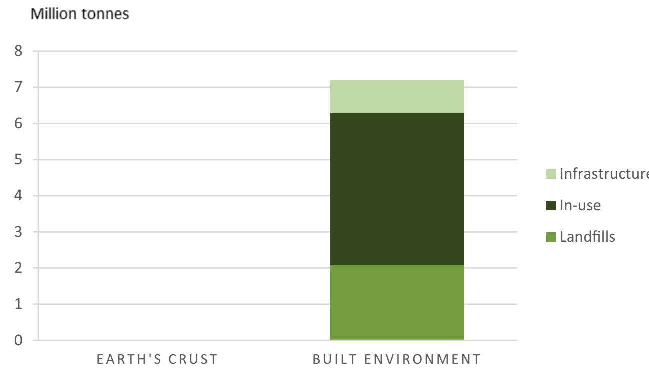

Fig. 3. The resource potential of aluminum in the Earth's crust compared to the built environment. The built environment is divided into different stocks. References: SGU (2014).

comparison would have included all waste deposits including slag heaps and other industrial landfills the potential would probably prove even greater considering that there are several aluminum plants in Sweden with landfills not accounted for.

Since the authorities evaluate the emerging alternatives, in this case landfill mining, based on the idea of how dominant modes of production work, which prevents them from grasping its multiple potential, the alternatives are seen as less attractive, and traditional mining becomes the preferable alternative. Instead of comparing the resource potential in landfills with the bedrock, the authorities could have compared the amount of minerals in landfills with those in-use, available for conventional recycling. Thereby, the potential of increasing the recycling flows by target landfills would have appeared significant. In addition, the whole idea of comparing mineral stocks based on the resource potential is based on how mines are assessed (cf. Payne, 1973), rather than, for example, the environmental consequences of extracting minerals from these largely different deposits.

If the comparison of the recycling potential and mining potential had been based on the consequences of extraction rather than on economic potential, the future potential would not necessarily be found in the bedrock. The reason is that the greatest potential in the Swedish bedrock is in low-grade deposits or in undiscovered, most likely low-grade reservoirs (SGU, 2014: 22). The consequences of extracting these low-grade metals are both socially and ecologically strenuous. For example, energy consumption increases exponentially with decreasing ore grade (UNEP, 2013).

5.3. Framing the environmental potential

The environmental impact of landfill mining is discussed by the SEPA (2013, 2015). However, in Report 1 where landfill mining is understood as a remediation activity, only the benefits from remediation and recycling are noted, while the risks and local impacts from the operation are not accentuated. In Report 3, where landfill mining is understood as a resource activity, the benefits of remediation as well as from avoiding primary production are less emphasized. The focus is instead on local environmental risk of resource recovery in terms of the spread of unwanted substances, gases, noise, and odor. Hence, the risks and gains are never contrasted with each other or with the environmental impact of mining. Instead, the SEPA concludes in the latest report that the environmental impact of landfill mining is uncertain and is therefore cautious about supporting such initiatives. Emerging niches are, however, always surrounded by many uncertainties, exemplified by the current debate of the environmental impact of organic food production (DeLonge et al., 2016) and biofuels (Tenenbaum, 2008), which are believed to threaten the global food supply.

The attitudes of supporting innovative recycling operations, however, also seem to depend on who is behind the evaluation. In the first report, landfill mining is understood as a remediation activity with environmental and economic benefits. Hence, the SEPA (2013) is positive to support landfill mining operations in this report. In the third report landfill mining is understood as a resource activity, with a limited potential compared to the bedrock. The SEPA (2015) is therefore negative to support landfill mining activities. In the second report too, landfill mining is perceived as a resource activity with a limited resource potential. In this report, however, the SGU (2014) is positive to support landfill mining operations. The differences lie in the fact that the SEPA, unlike SGU, also includes an economic and environmental analysis of the resource potential, which according to the SEPA has an uncertain outcome.

The reason why SGU (2014) can legitimize support only on the incidence of minerals, while the SEPA (2013, 2015), in addition, needs to demonstrate environmental and financial benefits of extracting these minerals depends largely on different organizational cultures. The SGU is under the *Ministry of Enterprise and Innovation* and thus has a clear business support role and looks primarily at minerals from a geological perspective, as a resource. The SEPA, on the other hand, is under the *Ministry of Environment and Energy* and perceives minerals from an environmental perspective, which includes a complex representation of minerals as both a resource and a pollutant (read: heavy metals). For SGU, resource occurrence seems to be reason enough for supporting an activity, while the SEPA demands certain and clear environmental advantages. As primary resources, minerals are the responsibility of the SGU and secondary resources and waste are the responsibility of the SEPA, there is a risk that secondary resource will meet higher demands for support than primary resources, which is already the target for a variety of subsidies in the form, for example, of exemption from the landfill tax (Johansson et al., 2014).

6. Conclusions

The ontological complexity of landfill mining, where several different objectives may be of relevance, makes it difficult for the authorities to evaluate landfill mining. The way the authorities frame landfill mining in their evaluations, as a remediation activity or a resource activity, has a decisive impact on their attitude towards landfill mining; becoming positive or negative, respectively. At the same time, the authorities are inconsistent in their framings of landfill mining. In Report 3, the resource potential is compared with conventional mining, while the tax situation is compared with traditional recycling. Thereby, the resource potential of landfills is presented as negative and the landfill tax as reasonable for landfill mining activities. If the resource potential instead had been compared with the recycling potential and the tax situation with mining, the potential would have been presented as significant in landfills and the landfill tax as unreasonable.

Evaluations, such as those highlighted in this paper, are typically detailed so as to avoid over-simplification. However, the detailed evaluations bring a narrow perspective that misses other necessary elements for policymakers to take a balanced decision. Therefore, for the authorities to assess initiatives towards a resource transition, broader tools and methods are needed that can embrace the whole ontological complexity of a phenomenon, a challenge that should attract the research community's attention. In principle this calls for evaluation tools that can include as many pros and cons of an activities as possible.

Secondary resources in landfills seem to lack an institutional affiliation. The SEPA commonly perceives minerals in landfills as pollution and is thus mainly in favor of handling them through decontamination measures. On the other hand, the SGU commonly perceives minerals as a resource to be found in the Earth's crust and is thus mainly in favor of traditional mining practices. Hence, the challenge of a transition towards dominant use of secondary resources requires more than just changed policies. To enhance the institutional capacity of a resource transition towards a circular economy, institutional change breaking up the current institutional structures is necessary. Secondary resources and primary resources should be governed in a similar way, perhaps under the same governmental structures.

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