URBAN MINING – PROSPECTING FOR METALS IN THE INVISIBLE CITY

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Abstract

In theory, 'urban mining' has a huge potential for enabling more efficient resource use and offering new business opportunities for the cleantech and recycling industries. This concept involves recovering technospheric stocks of previously employed natural resources that have been taken out of use without being collected for waste management. Such hibernating material stocks can be found in old water supply, sewage and power distribution networks – urban structures rich in for example iron and copper. This paper aims to analyze the potential for urban mining of the metals copper and aluminum from hibernating power and communication cables in Sweden. Emphasis is on the economic feasibility of two different approaches for realizing such initiatives. The results indicate that *separate extraction* of obsolete cables situated below ground in a city is not yet likely to be economically justified for power grid managers. Even in case of *integrated recovery* during other maintenance work on the grids, additional project costs often exceed potential revenues for the cables. In rural areas, however, both separate and integrated recovery of hibernating cables seem straightforwardly profitable, especially for obsolete copper cables belonging to the regional communication network. It is concluded however that the viability of urban mining is not only a matter of economics. Research aiming to analyze technical, economic, environmental and other institutional conditions for realization of urban mining is therefore strongly encouraged.

Keywords

Hibernation, Power and communication cables, Aluminum, Copper, Resource recovery, Economic feasibility.

1. Introduction

Massive amounts of natural resources have been extracted from their reservoirs and accumulated in buildings and infrastructure in order to support our affluence (e.g. Spatari et al., 2005; Kapur, 2006; Wittmer and Lichtensteiger, 2007). Over time, parts of these technospheric stocks have been taken out of use without being collected for waste management. Such accumulations of obsolete materials, still remaining in their original location but theoretically still accessible for recovery, have been referred to as hibernating stocks (Bergbäck et al., 2001; Hedbrant, 2003; Kapur and Graedel, 2006). Possible places where such hibernating materials could be found are old water or gas supply networks, sewage systems, power grids, and decommissioned military and industrial structures. These are all examples of large technical systems, which often are rich in metals like iron and copper (UNEP, 2010). In Sweden, for instance, hibernating cables situated in the present communication and power grids have been estimated to contain several hundred thousand tonnes of obsolete copper and aluminum (Wendell, 2005). Another perhaps more internationally recognized example of this phenomenon is out-of-date electronic equipment and other products temporarily stored in the attic of people's dwellings or elsewhere in the urban environment (Bertram et al., 2002; Kapur and Graedel, 2006; Müller et al., 2006).

So far, most of the research related to urban mining has focused on long-term potentials for conservation through increased recycling rates as the resource stocks in-use successively turn into waste (van Beers and Graedel, 2003; Gordon et al., 2006). The possibility of mining hibernating materials directly from their location in the built environment has however so far been largely disregarded. One reason for that is that there simply is a lack of knowledge regarding the actual occurrence of such obsolete urban resource stocks (Kapur and Graedel, 2006). However, even though such information about the quantity and location of hibernating materials is a necessity for assessing potentials, it is also insufficient because the feasibility of urban mining relies on many other conditions. No matter how large the potential of this so far largely theoretical concept appears on the societal level, it will in the end always be realized by individual companies for which benefits must simply outweigh costs.

This paper aims at taking a first step towards analyzing the economic feasibility of urban mining. In doing so, we quantify the costs and benefits related to extracting hibernating power and communication cables in Sweden, taking into account influencing factors such as technical, institutional and market conditions.

2. Analytical approach

Cables of copper and/or aluminum intended for communication and power transfer are widespread in our society. For Swedish conditions, the total stocks of copper and aluminum in such cable networks have been estimated at about 3,000,000 tonnes and 830,000 tonnes respectively (Wendell, 2005). Cables no longer in use but still located in the grids are mainly to be found in local and regional power grids, and in the so-called transport networks of the communication network, Table 1. These types of grids have therefore been in focus for the analysis of this paper on conditions for realizing urban mining of hibernating cables. In Sweden, a handful of companies divide up the regional power grids. These grids are in general found in rural areas and mainly consist of medium-voltage cables (36–72 kV), either made of copper, or aluminum with a copper shield. On the local level there are multiple actors distributing power to final consumers. Such local grids are primarily situated in city environments, consisting of low-voltage cables (0.4–24 kV) with less copper and/or metal content per meter of cable. Furthermore, cables in hibernation are mainly located under ground, i.e. buried in soil, either as whole parts that have been disconnected from the grids or co-located in shafts together with other types of cables still in operation.

Table 1. Stocks of copper and aluminum in hibernation in Swedish regional and local power grids and the communication network, in tonnes, 2005 (Wendell, 2005).

Type of grid	Type of cable	Cu, tonnes	Al, tonnes
Communication grids	Transport networks (Transport communication copper cables)	220,000	n.a.
	Local access networks	negligible	n.a.
Regional and local power grids			
	Medium-voltage cables, 36-72 kV	190,000	40,000
	Low-voltage cables, 0.4-24 kV	200,000	140,000

Even though the figures in Table 1 above involve uncertainties, it is clear that the stocks of copper and aluminum hibernating in communication and power cable networks are of a substantial order of magnitude. They can for example be related to the annual inflows of copper and aluminum domestically used for communication and power cables, which in the early 2000s were estimated at about 20,000 tonnes respectively. Furthermore, there might well be hibernating stocks of metals in other types of cables for communication and power transfer, e.g. in buildings, sea cables, and electr(on)ic products. However, due to the present

lack of knowledge regarding the occurrence of such obsolete metal stocks, they are not included in this paper.

For managers of power and communication networks, urban mining initiatives would generate revenue from the extracted hibernating cables. This revenue, paid by metal recycling companies, is largely dependent on the metal content of the cable in question and follows the market prices for metals (in summer 2010 this was 5.45 € per kg copper and 1.6 € per kg aluminum (17 June 2010)). In all, seven types (1-7) of hibernating cables, containing different amounts and types of metal, were included in the economic analysis, Table 2.

Table 2: Types of cables in hibernation, their main location and typical content of copper (Cu) and/or aluminum (Al) included in the economic analysis of urban mining on Swedish power and communication networks (calculated based on Wendell, 2005 and SwedEnergy, 2009)

Type of cable	Main location	kg Cu/m	kg Al/m
Cable 1: 6-24 kV, Cu	City environment	3,26	
Cable 2: 6-24 kV, Al	City environment	0,13	1,89
Cable 3: 0,4 kV, Cu	City environment	0,83	
Cable 4: 0,4 kV, Al	City environment	0,36	2,03
Cable 5: Comm. cable, Cu	Rural areas	12	
Cable 6: 36-72 kV, Cu	Rural areas	6,4	
Cable 7: 36-72 kV, Al	Rural areas	0,3	3,3

Based on the above, four scenarios were developed for calculation of costs related to recovery of the hibernating cables 1-7 (cf. Table 2): A) Separate cable recovery in city environment; B) Separate cable recovery in rural areas; C) Integrated cable recovery in city environment during other maintenance work; and D) Integrated cable recovery in rural areas during other maintenance work, Table 3. Separate cable recovery in a city environment incurs many different project costs, all of which have to be allocated to the extraction of the hibernating cables; costs for excavation and site restoration (including asphalting), temporary storage of excavated soil, land rental from municipality, shutting off traffic and handling of extracted cables. The reason why costs for “temporary storage of excavated soil,” “land rental from municipality” and ”shutting off traffic” were not included in Scenario B

is that such expenditures do not appear or are marginally low in rural areas. These calculations of costs related to Scenario A and B were based on information about excavation work provided by the power grid manager in the city of Linköping, Sweden (Utsikt, 2009). Integrated cable recovery during other maintenance work on the networks, as in Scenario C and D, would add some additional costs compared to regular maintenance projects such as supplementary time for project planning, excavation, shutting off traffic, and extraction and transportation of cables to metal recycling companies. Data on the magnitude of such additional expenditures for recovery of hibernating cables were taken from SwedEnergy (2009), an industrial organization representing companies involved in the production, distribution and trading of electricity in Sweden. Finally, all four scenarios include the cost for handling of excavated cables that is charged by the metal recycling companies for treatment and recycling expenditures, i.e. in 2010 0.3 € per kg of cable (Lind, B., Stena Recycling, personal communication 6/17/2010).

Table 3. Type of costs included in Scenarios A-D for recovery of cables in hibernation in city and rural environments, x full cost included, (x) only additional costs for cable extraction included.

Scenario	A	B	C	D
Type of cost	Separate recovery, city envir.	Separate recovery, rural areas	Integrated recovery, city envir.	Integrated recovery, rural areas
Handling of excavated cables	x	x	x	x
Cost for excavation	x	x	(x)	(x)
Storage of excavated soil	x			
Site restoration (incl. asphalting)	x	x		
Land rental from municipality	x			
Cost for shutting off traffic	x		(x)	(x)

3. Economic feasibility of extracting obsolete cables in city and rural environments

3.1. Separate cable recovery of hibernating cables

In Sweden, excavation in a city environment is expensive since such work generates many different operational costs. The actual excavation and then restoration (including asphalting) of the site in question typically account for more than 80% of the total project cost (i.e. 110 € per meter of excavated shaft) while the remaining part is the expense of shutting off traffic,

temporary storage of excavated soil, etc. Local power grids that are situated in such environments also mainly consist of low-voltage cables, which are generally less rich in metals than cables in regional networks. Initiatives involving separate recovery of hibernating cables in cities therefore do not yet seem an economic option for power grid managers, Figure 1. This is despite the fact that present market prices for copper and aluminum are relatively high. In fact, the results show that in a city environment revenues that could be obtained from hibernating power cables are not even close to outweighing the costs of separately extracting them.

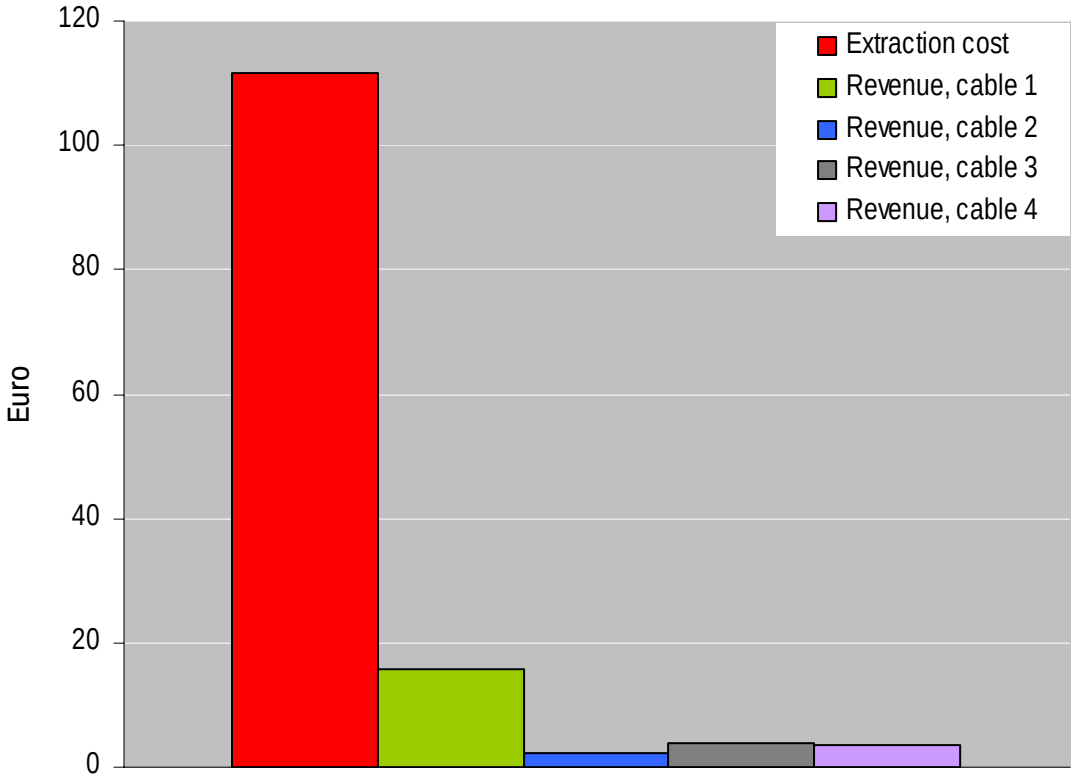

Figure 1. Scenario A: Total cost for separate extraction of hibernating cables in city environment versus revenues for different types of recovered cables (Cable 1=6–24 kV copper power cable; Cable 2=6-24 kV aluminum power cable; Cable 3=0.4 kV copper power cable; Cable 4=0.4 kV aluminum power cable). The data is presented in Euros per meter of excavated shaft.

Separate extraction of hibernating cables in regional power grids seems to be more easily justified from an economic perspective, Figure 2. There are several reasons for that. First of all, excavation in such rural environments, e.g. in the unpaved side of roads, only renders about 1/5 of the corresponding costs occurring in a city, i.e. 15 € per meter of excavated

shaft. Regional power grids and communication networks also generally involve cables with significantly higher copper concentrations. This is especially true for transport communication cables, typically containing 12 kg of copper per meter. The economic viability of such initiatives however largely relies on what type of cable is hibernating. For instance, despite the relatively low costs of excavation work in rural areas, separate recovery of cables with aluminum conductors is not economically justified.

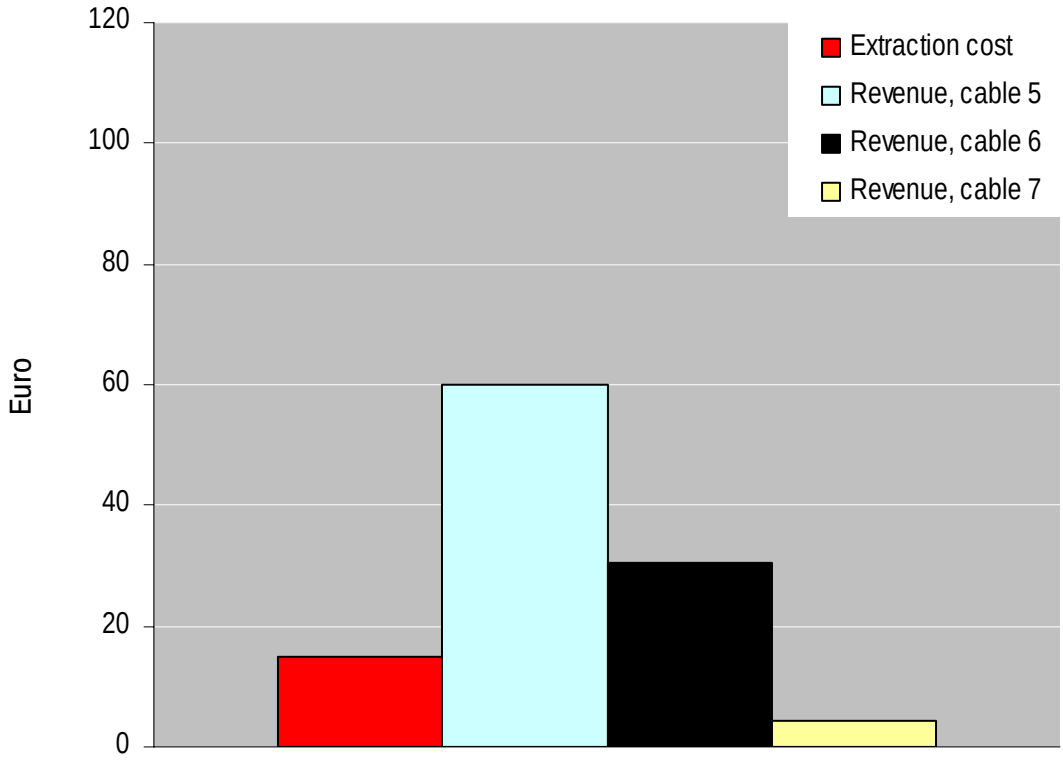

Figure 2. Scenario B: Total cost for separate extraction of hibernating cables in rural environment versus revenues for different types of cables (Cable 5: Transport communication copper cable; Cable 6: 36-72 kV copper power cable; Cable 7: 36-72 kV aluminum power cable). The data is presented in Euros per meter of excavated shaft.

3.2. Integrated recovery of hibernating cables

A more viable approach than separate recovery could be to extract hibernating cables simultaneously as other maintenance work is conducted on the networks. The regular project costs would then remain the same and could thus not be allocated to the cable recovery. Such an integrated approach would however cause additional expenses (e.g.

supplementary time for project planning, excavation and extraction of cables), which, dependent on case-specific conditions, i.e. exactly where in a city the excavation takes place, could vary from 5 € to 21€ per meter of excavated shaft (on average estimated at 13€). Even if the conditions for integrated recovery are more favorable, the results show that applying this approach to extracting hibernating cables in a city environment would still not be profitable for managers of power grids for most of the studied cables, Figure 3. It is more or less only for 6-24 kV cables with copper conductors, typically containing about 3 kg of copper per meter, that such initiatives could generate an economic surplus.

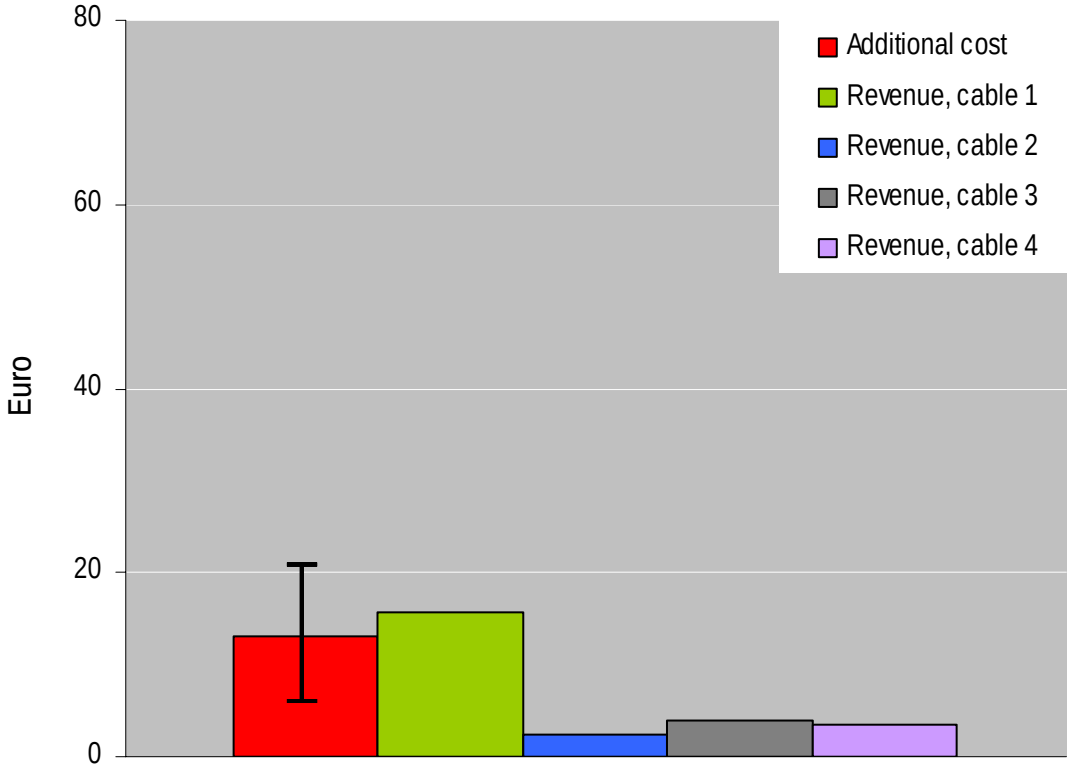

Figure 3. Scenario C: Estimated additional cost for integrated extraction of hibernating cables in city environment (including an uncertainty interval) versus revenues for different types of cables (Cable 1: 6-24 kV copper power cable; Cable 2: 6-24 kV aluminum power cable; Cable 3: 0.4 kV copper power cable; Cable 4: 0.4 kV aluminum power cable). The data is presented in Euros per meter of excavated shaft.

For extraction of obsolete cables situated in rural environments, the results for the integrated approach are similar to the results obtained for separate recovery, Figure 4. As long as the

hibernating cable in such regional networks involves copper as the main conductor, according to the results recovery is straightforwardly profitable.

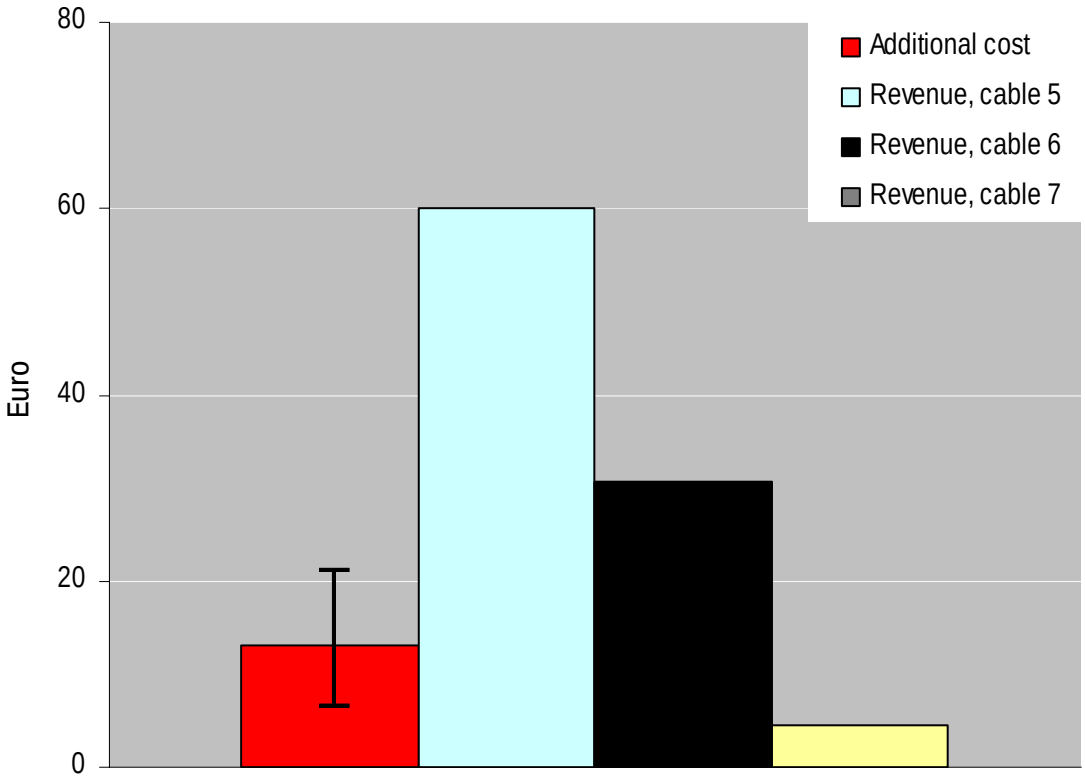

Figure 4. Scenario D: Estimated additional cost for integrated extraction of hibernating cables in rural environment (including an uncertainty interval) versus revenues for different types of cables (Cable 5: Transport communication copper cable; Cable 6: 36-72 kV copper power cable; Cable 7: 36-72 kV aluminum power cable). The data is presented in Euros per meter of excavated shaft.

4. Concluding discussion

At present, separate extraction of cables hibernating below the ground in a city is not likely to occur in Sweden. In order to make such initiatives an economic option for power grid managers, the present copper and/or aluminum prices would have to increase by several orders of magnitude. Alternatively, there is a challenge for developing technology that enables extraction of hibernating cables without having to open up the entire shaft, which in a city environment is extremely costly. Even in a case of integrated recovery during other maintenance work on the city grids, additional project costs often exceed potential revenues for hibernating cables. In rural areas, however, economic incentives for managers to

consider recovery of obsolete copper cables situated in their networks are more prominent. With today's copper price, it is estimated that the potential revenue per meter of shaft is almost four times the cost of extracting transport communication cables and twice the cost for medium-voltage power cables.

So, why isn't recovery of hibernating cables in rural areas already common practice? Although addressing this question in detail is far beyond the scope of this introductory study, some plausible reasons can be outlined. In order to be able to collect and recover obsolete materials in general, information about their exact location is of course fundamental. In a recently completed study on hibernating power cables in two Swedish cities, Linköping and Gothenburg, it was found that such detailed data is readily available and kept within the managers' Geographical Information Systems, GIS (Krook et al., manuscript). This might however not necessarily be the case for regional cable networks or for local power grids situated in other cities. It is also important to understand that metal recovery is a largely peripheral activity for cable network managers. Their core business is instead to secure efficient distribution and transferring of telecommunications or power to final consumers (cf. Krook et al., 2006). Facilitating urban mining might therefore rely on the development of new forms of collaboration between actors belonging to totally different lines of business, e.g. material companies, waste management contractors and infrastructure managers. Obtaining such cross-sector partnerships has traditionally proven difficult in Sweden since there is a tradition of keeping and solving issues separately within each societal sector (cf. Jonsson et al., 2000; The Swedish Environmental Protection Agency, 2001).

The realization of mining hibernating cables is thus not strictly a response to economic conditions but is also influenced by other institutional issues. For instance, if such recovery should prove beneficial from an environmental perspective, land owners might require that no cables be left behind on their property after being brought out of practice.

In this study, we have only addressed the conceivability of urban mining related to one particular type of hibernating stock. As has been pointed out previously, however, such obsolete materials might occur in many places in the built environment. It is likely that the economic conditions for collection and recovery of different hibernating stocks vary due to factors such as location (e.g. above or below ground), type of materials and their present market values, technology needs, involved actors, regulatory implications and so on. This introductory study is however part of an ongoing research program in Sweden entitled

"Urban mining: laying the foundation for a new line of business." The overall aim of this three-year program is to develop systems solutions facilitating the emergence of this potentially new business area. Specific projects aims are to i) analyze why the phenomenon of hibernation occurs and quantify existing obsolete stocks of natural resources in the Swedish built environment; ii) assess the main drivers, enablers and barriers for mining such urban ores in order to develop conditions facilitating realization; and iii) evaluate the net economic and environmental performance of urban mining case studies in order to identify critical factors for beneficial implementation. Emphasis is strictly on large technical systems and the technical, economic, environmental and institutional conditions for realizing urban mining on such systems will be studied in detail for three different cases: the city of Norrköping, the Swedish military defense and the national railway system.

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