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Assessing the Urban Mining Potential in the City of Huddersfield, UK

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Abstract.

With the increasing demand of metals from industrial facilities and the construction sector, the abundance of discarded metals within the infrastructure of a typical city may be considered as an attractive source for metal recovery. The term "urban mining" refers to the process of recovering metals from secondary metal stocks in urban locations, which provide an alternative resource to conventional mountainous mines. An integrated urban mining potential assessment comprises of two steps: (a) mapping and size estimation of a certain metal reserve and (b) evaluation of the economic feasibility of its recovery, by determining the necessary extraction process. The infrastructure systems (or infrasystems) in the city of Huddersfield, and UK in general, are to a great extent buried underground and surface cables are usually immediately removed after being decommissioned. Thus, the major infrasystems (and the corresponding metals) in the studied region are (a) AC/DC power (Cu/Al), (b) telecommunication (Cu), (c) natural gas (Fe) and (d) water mains (Cu/Fe). In the current study, we focus on the assessment of urban iron mining potential, through mapping the spatial distribution of hibernating iron deposits in Huddersfield, identifying potential hotspots in the city and assessing alternative options for their recovery.

Keywords: Urban Mining, Huddersfield, Iron, Gas Network

1. Introduction

One of the current major environmental concerns is the depletion of the finite fossil resources. The issue is further aggravated with the increasing demand of metals from manufacturing industrial facilities and the construction sector. On that note, both the European Commission (2014) and DEFRA (2012) have included metals in their proposed lists of key waste materials, which should be the focus of new actions in order to improve both the environmental performance and the economic output. The term Urban Mining was first introduced in the late 1980s as a term which described the recovery of metals from discarded manufactured products in an urban setting (Nanjyo, 1988). Since then, the term has evolved and has broadened and nowadays expresses all the actions required in order to reclaim compounds, energy and elements from various types of anthropogenic stocks. These may include infrastructure, abandoned buildings and discarded products as well as environmental media receiving anthropogenic emissions (Cossu and Williams, 2015). During the last 15 years, typical urban infrastructure, which, over time, has become obsolete (e.g. buildings, cables, pipelines) but has not been removed, as well as urban waste electrical and electronic equipment (WEEE) has been thus considered as significant alternative sources of scarce resources (Bergbäck *et al*, 2001). It has been argued that metal recovery from waste can be more resource efficient than using metal from mining ores; indicatively it has been estimated that approximately 200-350 grams of gold (Au) can be found in 1t of PC circuit boards or cell phones, when only 5 g Au can be found in 1 t of ore (Caffarey, 2012). Similarly, 10 kg can be retrieved from 1 t of ore extracted, whereas the same value for 1 t of printed circuit boards is 330 kg (Geyer and Doctori Blass, 2010). The first step towards the recovery and exploitation of such resources is the mapping of the hibernating metal stock. The most widely used method to assess metal stocks, from human activities is Material Flow Analysis. It has been already applied to quantify the existing metal stocks related to either urban infrastructure (Wallsten *et al*, 2013) or WEEE (van Eygen *et al*, 2016). However, the level of aggregation of a typical MFA output is quite high and the results are presented on a city/regional level. Thus, they are not useful for decision making related to the implementation of the extraction process. For that reason, MFA is usually paired with a Geographic Information System (GIS) to add a more detailed spatial distribution analysis of the stocks (van Beers and Gradel, 2003; Tanikawa and Hashimoto, 2009). The use of GIS could also support extra details such as the depth of the stock or multiple layers of resources. However, Wallsten *et al.* (2015) argue that even the use of a GIS will not give the necessary low level aggregation and will be limited to a city or, in the best case, district level. They also suggest that an even higher resolution (possibly at street level) is required to perform a complete and accurate economic and technological assessment of the urban mining potential. Having that in mind, the objective of this paper is to assess the urban mining potential that is currently in hibernation in the city of Huddersfield, at the lowest possible level of aggregation. Primary data with street-level detail have been used in order to map and characterize the hibernating iron stocks from the gas supply network and the economic feasibility of their recovery is assessed.

2. Methodology

The analytical approach that has been used can be divided into three steps. In the first step, the gas supply network in the city of Huddersfield is characterized based on its total length, location and operational status (in use or abandoned). The corresponding stock of iron is subsequently estimated by multiplying the length of pipelines with an average iron concentration. Finally, the economic feasibility of recovering the hibernating metals is assessed based on the costs of extracting them and the expected revenues.

2.1. Data Collection

Each urban setting has its own distinct infrastructure configuration; thus it is critical to highlight the milestones related to the historical and industrial development of the region to understand the traits of each urban mine (Wallsten *et al.*, 2015). Huddersfield is a manufacturing town, located in West Yorkshire in the northern part of England and its population exceeded 160,000 at the 2011 census. The town was historically the home of woolen textile industries, and the chemical and engineering industries that were developed along them in order to provide all the necessary resources. The textile industry is currently in decline but stills plays a significant role in the town's economy, by producing large quantities of woolen products. The major types of the currently available infrastructure in the city of Huddersfield are water pipelines (potential source of Cu/Fe - managed by Yorkshire Water), gas pipelines (potential source of Fe - managed by Northern Gas), power cables (potential source of Cu/Al - managed by Northern Power Grid) and abandoned public buildings (managed by the local municipality). Airborne and surface cables are usually removed from their initial location after becoming obsolete. Moreover, manholes and street transforms were not included in the analysis, although they might be a significant source of hibernating metals (van Beers and Gradel, 2007). The infrasystem that was chosen to be included in the study is the low pressure gas network and the selection was made based on data availability and ease of processing.

2.2 Hibernating Iron Stocks

The key parameters required to estimate the hibernating iron stock are (a) the total length of the abandoned pipe network, and (b) the metal content per metre of pipeline. A detailed layout of the gas pipeline network of the city of Huddersfield was provided by Northern Gas and is presented in Figure 1 (NGN, 2017). The metal content of a typical gas steel pipe was assumed to be 34 kg iron / metre, based on literature values (Wallsten *et al*, 2013).

2.3 Economic Feasibility of Metal Recovery

In order to render the recovery of the hibernating stock economically feasible, the selling price of the metal should be such so that the total expected income exceeds the extraction costs. The latter mainly depend on two main parameters:

(a) Urban relief (which indicates how densely built are the corresponding urban districts; meaning that the recovery in more dense regions is more expensive); and

(b) Surface material and corresponding hardness (where hard surfaces make it more expensive to recover materials) (Wallsten *et al*, 2015).

According to Krook *et al*. (2011), two alternative approaches can be examined in order to assess the economic feasibility of metal recovery:

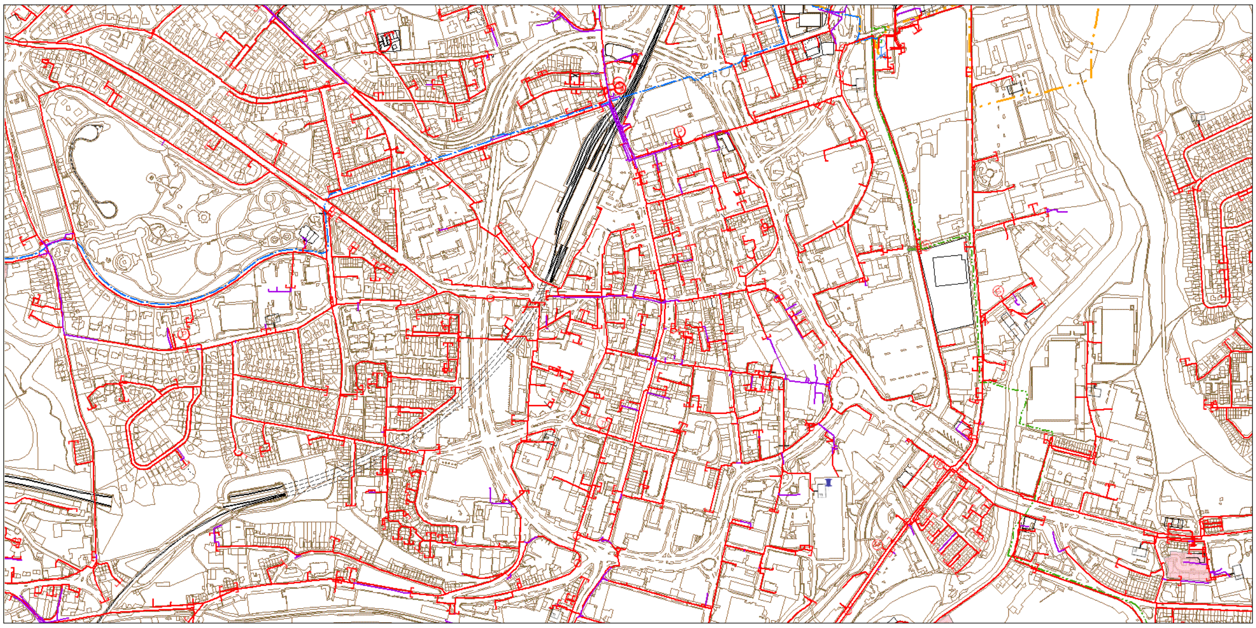

Figure 1. Map of in-use (red bold lines) and abandoned (purple bold lines) low pressure gas pipelines in the city centre of Huddersfield, retrieved from the GIS database of Northern Gas, the gas network manager (Map scale 1:5000)

(a) Separate recovery, when digging works are performed exclusively to recover the hibernating stock and the total project costs are fully allocated to the extraction; and

(b) Integrated recovery, when digging and metal recovery is combined with other maintenance work and only one part of the project costs is allocated to the extraction process.

Wallsten *et al*. (2015) estimated that the extraction costs in the case of separate recovery can range from £45-80 per meter, depending on the depth, the urban density and the surface hardness. Krook *et al*. (2011) calculated that the total project cost for cable extracting is approximately £100 per metre in the case of separate recovery but can drop down to £4-18 per metre in the case of integrated recovery.

3. Results

A detailed mapping of the gas infrastructure located in the city centre was performed (including roughly all the districts in the HD1 postcode). The total surface of the studied area is 4.2 km^2 and is divided into 12 similar sub districts, each one of which has an area of approximately 0.26 km^2. The total low pressure gas pipeline length is estimated to be 85.6 km. It was calculated that the total length of the abandoned pipelines is 7.4 km, which corresponds to 9.6% of the total gas pipeline network length. The equivalent mass of the hibernating iron stock is 254.1 tonnes. By extrapolating this value to the total surface of the town of Huddersfield, it can be estimated that the total iron stock should exceed 3000 tonnes.

Figure 2 presents the spatial distribution of the hibernating stock of iron in the city centre of Huddersfield. The mapping reveals that the districts located in the northern part of the city have the higher urban mining potential. Districts (2) and (3) contain approximately 24% of the total hibernating stock and the share of the abandoned network reaches 34% of the total gas pipeline network. On the contrary, the regions located in the western part of the city centre are characterized by a low urban mining potential. The share of the abandoned pipelines merely exceeds 4.1%, which can be explained from the fact that there are several parks in these districts. The total revenue from the recovery of total hibernating iron stock is estimated to be approximately £25,400, if we assume an average selling price of recycled steel scrap of £100/tonne. Since the total length of the abandoned network is approximately 7500m, it is apparent that separate recovery is not economically feasible. Integrated recovery will be feasible only if the extraction cost is at the lowest end of the expected range (<£4/m). However, such a project will still be marginally profitable but it will be a challenging task to support such an investment and proceed with its implementation.

Table 1. Total in-use and hibernating stocks of iron in the low pressure (LP) gas network at the city of Huddersfield

Map	Total Length of LP Gas Network (m)	Total Length of Abandoned Network (m)	Share of Abandoned Network	Hibernating Stock of Iron (tonnes)
1	7180	200	2.8%	6.8
2	1267	501	39.6%	17.0
3	5577	1300	23.3%	44.2
4	1549	121	7.8%	4.1
5	5829	249	4.3%	8.5
6	6793	247	3.6%	8.4
7	5268	983	18.7%	33.4
8	3123	55	1.7%	1.9
9	3531	288	8.2%	9.8
10	6130	136	2.2%	4.6
11	7509	1169	15.6%	39.8
12	5413	693	12.8%	23.6
13	3655	131	3.6%	4.4
14	4695	749	16.0%	25.5
15	5047	348	6.9%	11.8
16	5548	304	5.5%	10.3
	78114	7474	9.6%	254.1

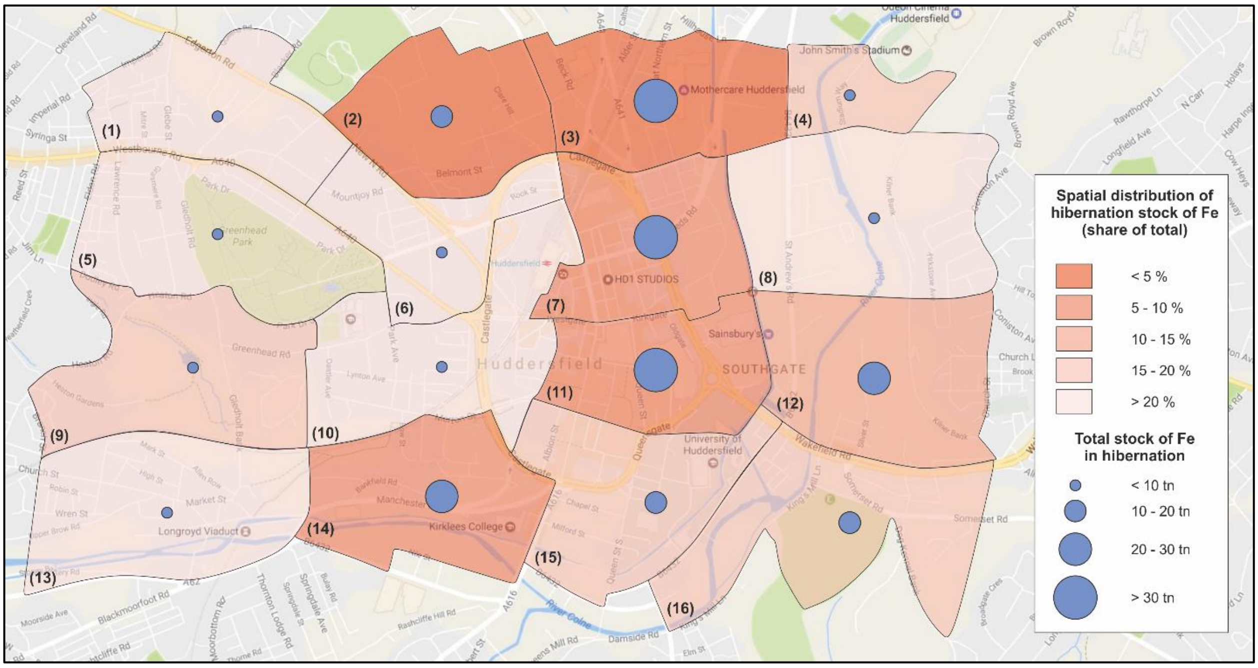

Figure 2. Spatial distribution of the hibernating iron stock in the city centre of Huddersfield

4. Conclusions

The majority of metal hibernating stocks are located in the cities. However, the nature of the cities (residential areas, low noise and low disturbance levels) poses great difficulties to their extraction and that is the main reason that abandoned infrastructure is not originally recovered. For this purpose, a holistic approach is required which will take into account both the hibernating stocks of more than one resources and the schedule of already planned maintenance/digging activities in the urban setting. In the case of city of Huddersfield, it is apparent the recovery of the iron stocks is not economically viable in the case of separate recovery. When considering integrated recovery, the project might become marginally profitable but it will be still difficult to actually implement it. However, it should be noted that only one type of infrasystems/metal was mapped and assessed. If more layers of metals are added to the existing mapping, this might reveal patterns of high metal concentration and consequently regions with high urban mining potential. Thus, the suggested next steps for further research would be to:

- Expand our study area and include the suburbs of Huddersfield in order to further highlight the urban mining hotspots;
- Include more than one infrasystems by retrieving data for the water pipeline network and/or the power grid, from the corresponding stakeholders;
- Get actual data for the expected extraction cost in the city of Huddersfield, by interviewing the relevant contractors; and
- Incorporate in the analysis the expected maintenance and refurbishment works in the region, which might lower even more the integrated recovery extraction costs.

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