Prospecting the urban mine of Amsterdam
Prospecting the Urban Mine of Amsterdam

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Executive Summary

The Circular Economy is embraced by many as a solution for the increasing pressure on resources and the environment. Its aim is to keep resources in use in society in some way, to prevent creating waste and to reduce the need for virgin materials. Urban mining is one of the options to do that. Urban mining considers stocks of materials in society as potential mines. Similar to geological mining, a first step in exploiting the urban mine is prospecting. How much of the material is actually present in the mine, in what form does it occur and can it be mined profitably?

PUMA hopes to contribute to the development of the circular economy by prospecting the Amsterdam urban mine in residential buildings, with regard to its potential and its limitations as a source of secondary copper, steel and aluminium. This work contains of two parts:

- Building a database using publicly available data, and constructing the “geological” map of the urban mine of Amsterdam
- Exploring options to exploit the urban mine of Amsterdam.

The database and map have been constructed based on the following information:

- Information on the location, type, function and age of residential buildings as provided by the BAG, AHN and several other sources
- Information on the metal content of the buildings, generated in a literature study done by TU Delft and checked by Metabolic in a ground truth exercise.

With considerable margins of error, we have been able to generate both a database and a prospecting map. The database with links to original data is available at https://github.com/waagsociety/puma. The prospecting map visualising the data can be found at http://code.waag.org/puma/, eventually it will be stored at http://www.ams-institute.org/solution/puma/. The stock of metals in buildings appears to be considerable, however, not directly available for mining as it is in use. A mining plan should take into account, therefore, when these stocks become available.

Urban mining is a new area of research, and urban mining systems presently do not exist yet. Therefore, the first steps of exploiting the mine by making a mining plan are preliminary and exploratory. In the PUMA project we approached it by creating different “background” scenarios along two axes:

- Scale level: local to global
- Driving force: markets or governments

This exercise has provided some valuable insights:

- Market oriented scenarios will probably result in different construction practices as policy oriented scenarios. Under market oriented scenarios, a trend towards lighter building, modular building and shorter life spans is expected, making recycling easier and more profitable. Under policy oriented scenarios, the trend might be to lengthen life spans and reduce the demand in that way.
- The urban mining supply chains have both local and global aspects. It is not possible, nor desirable, to create completely local urban mining systems. Mines are local and the information base must be built up from the local level, but markets for secondary materials are global and cannot be transformed to local – that will be technologically inefficient and will lead
to disparities in supply and demand.

- An incentive towards establishing urban mining systems is presently missing. Markets for secondary materials are unstable. This must be corrected for urban mining to become a profitable business, either by financial incentives such as a resource or carbon tax, or by dedicated policies. Such incentives cannot be local.
- The information system for urban mining must be built up and maintained by some sort of a supply chain manager, and be made available throughout the supply chain. The BIM system appears to be a good starting point. This system must have a local component, but should be linked to (probably simpler) higher-level databases to ensure comparability and gain relevance.
- Residential buildings are relevant stocks from the point of view of their size, but other stocks are potentially easier to mine. An urban mining system should consider these other stocks as well: commercial buildings, infrastructure, vehicles, and large consumer appliances are all relevant to include.
Prospecting the Urban Mine of Amsterdam

I Introduction

“Effective use of raw materials is one of the focal points in the first sustainability programme of the city of Amsterdam”, is a quote from “Amsterdam Definitely Sustainable” (Amsterdam Beslist Duurzaam, 2011-2014). According to this plan, the effective use of raw materials involves thinking in terms of cycles. In the document “De Circulaire Metropool Amsterdam” (2014), the intention is published to convert Amsterdam to a circular economy for materials. “Amsterdam Circulair” (2015) tries a first roadmap specifically for the built environment and biomass.

The circular economy is a popular concept nowadays, broadly aiming at keeping materials in use for as long as possible, in order to avoid having to produce new materials. This involves changes in the whole economy. Technical changes are needed to innovate the whole production consumption chain: design of materials for recycling, design of products for recycling or remanufacturing, refurbishment, reuse, design of recycling processes etc. Organisational changes are needed to facilitate all this: to set up cooperation and information throughout supply chains, to establish collection systems, and to adapt legislation to allow for it. Business models have to be developed to grasp these new opportunities. Transforming our society towards a circular economy is a major undertaking, that is now being explored with great enthusiasm because of its win-win aspects: saving resources and protecting the environment while at the same time creating new jobs and growth.

Many concepts can be covered under the broad umbrella of the circular economy. Urban mining is one of those concepts. It is a relatively new concept, for which now a small body of literature is available. Its origin lies in the study of material flows, and more precisely the urban metabolism studies that have been conducted since the end of last century (for an overview, see a.o. Kennedy et al., 2011 and Zhang, 2013). Its aim, again broadly speaking, is to use obsolete stocks from our economy as a source of new, though secondary, materials. From the literature (see for example the overview article of Krook & Baas, 2013, and the typology introduced by Johansson et al., 2013), it is clear that there is not yet a generally accepted definition, nor a generally accepted idea of which specific stocks are included. Various publications mention the following stocks:

- Stocks of products in use in society (Baccini & Brunner, 2012). Specific products researched are electric and electronic appliances such as laptops, computers, mobile phones, washers, dryers, refrigerators etc. Another category of “products” involved the built environment: construction materials, but also cables, pipes, gutters, wires and other types of infrastructure.
- Hibernating stocks (Krook et al., 2011). These are stocks that are no longer in use, but have not entered the waste stage yet. Large hibernating stocks can be found in the ground, as abandoned pipes, cables etc.. Relevant stocks can also be found in attics, basements and drawers: abandoned products that for some reason have not been trashed.
- Stocks on landfills (Cossu, 2013). Waste products in many countries end up on landfill sites, leading to a concentration of materials that could potentially be mined.
- Stocks in slag and tailings (Johansson et al., 2013). This waste contains metals, and as technology progresses it becomes economically viable to extract metals from former waste streams.

Johansson et al. (2013) also include “dissipated stocks” in their technology, pointing at polluted soils...
and other environmental compartments, but conclude at the same time that this stock is not very feasible to mine.

The common element is extracting materials from stocks that are or have been in use. For the rest there are substantial differences. One difference refers to the processes included in the urban mining concept. There is agreement on recycling being a key process: the secondary production of materials. Some include also the other “re” concepts: reuse, refurbishing, remanufacturing, or even repair. These, obviously, refer to stocks in use and hibernating stocks only. Another difference is in the materials included. Most urban mining studies are on metals. Some studies also include construction minerals, or plastics. In some cases, biomass is even included. Yet another difference is in location. Some consider only stocks in cities, while others include the whole anthroposphere. The business development part that is so important in the circular economy framework is also important for urban mining: it will only become practice when there is money to be made. This will differ considerably among the various materials and appliances.

As the scope differs, also the place of urban mining within the Circular Economy framework is different, ranging from recycling to more or less encompassing the whole of the circular economy.

As there is no generally accepted definition to start from, we have to make our own demarcation of the field. In our conception of urban mining, we have no prior exclusion of different types of materials, although we consider metals to be the most relevant type of materials. We would exclude slag, mining waste and dissipated stocks, but include all other types of stocks. We would not include repair, reuse etc., as this applies to products, not materials. Our idea of urban mining is to produce secondary materials from obsolete societal stocks. The study of stocks in use is important, as these stocks will one day become obsolete. In this project, we take the analogy with “regular” mining seriously and view the urban environment as a mine that can provide us with materials (as in done by Wallsten et al., 2013). This implies we include recycling as the actual production process of secondary materials, but also include a whole series of activities that have to do with prospecting, exploring and setting up the whole production line. In the figure below, the position of urban mining in the whole materials life cycle is depicted.

Figure 1 Different types of mining and their main objectives

Source: Johansson et al., 2013.

In addition, we have to make some practical demarcations to keep the PUMA project manageable. We
include, for such practical reasons:

- Metals, more specifically copper, aluminium and iron & steel
- Stocks-in-use, and to some extent hibernating stocks, focusing on appliances in the built environment

Of all the different materials, metals are most suited for closing cycles. Large amounts of metals can be found in the urban built environment, in applications with sometimes very large life spans. This implies that the prospecting part of the mining process is complex, and therefore that a “mining” approach can have an added value.

A city’s built environment can be seen as a mine, to be exploited as a source of secondary materials. However, in order to realise this potential some issues need to be resolved. As a starting point, information is required on the quantity and quality of these metals, as well as on the time frame in which the metals will become obsolete, and therefore available for urban mining. To know at what moment and to what extent the urban metals can provide for future demand an exploration is needed. Like the geological survey of potential mines by mining companies, the urban mine will have to be prospected as to viability and value. Only then will we be able to include urban mines in our planning for the future materials supply of societies.

PUMA contributes to the development of the circular economy by prospecting the Amsterdam urban mine with regard to its potential and its limitations as a source of secondary metals. This work contains of two parts:

- Building the database and constructing the “geological” map of the urban mine of Amsterdam (Part II)
- Exploring options to exploit the urban mine of Amsterdam (Part III)
II A database for the urban mine of Amsterdam

II.1 The PUMA method: how to construct an urban mining database

Prospecting the urban mine of Amsterdam is primarily a major effort of data collection. We need to know how much metals are in the mine, where they are, and when they might become available for extraction.

Four types of information are required to chart the urban mine:

1. The products, appliances, types of infrastructure or buildings that contain the metals
2. The location and spatial distribution of those products
3. The metal content of those products.
4. The life span of the appliances and the present life span distribution of the stocks-in-use.

Ad 1. and 2. Starting from the built environment, there are various relevant databases available that contain information on both the products (houses) and the spatial location of those products. A lot of information for buildings, both residential and industrial/commercial, is available from the BAG database (Basisregistratie Adressen en Gebouwen), not just for Amsterdam but for all municipalities the Netherlands. In the BAG, basic data on all buildings and addresses is stored (http://www.basisregistratiesienm.nl/basisregistraties/adressen-en-gebouwen). This database contains the following for each address in Amsterdam:

- Address and postal code
- Year of building
- Function of building
- Floor surface area
- Status (in use or not)

Additional data on the buildings are also available via the BAG, such as the outline/footprint of the building which can be computed based on the contours that are available as a shapefile (“pandcontouren”). The BAG is maintained and published by The Netherlands’ Cadastre, Land Registry and Mapping Agency – in short Kadaster. Information on the height of buildings is available from Actueel Hoogtebestand Nederland (AHN), maintained and published by Waterschappen, Rijkswaterstaat en Provincies. Both are accessible via https://www.pdok.nl/.

BAG and AHN are combined by the company ESRI, producer of the ArcGIS software, to a BAG-3D information system. Analysis and visualisation of the data is done in ArcGIS 10.2, QGis and Python. The BAG-3D database is accessible only with ArcGIS. However the two uncombined databases are accessible for all.

The BGT (Basisregistratie Grootschalige Topografie) contains information on many different topics in a spatial grid. Rails, pipes, cables, street furniture etc. can be visualised in maps for the Netherlands, at a very detailed level. This information can be found at http://www.digitaleoverheid.nl/onderwerpen/stelselinformatiepunt/stelsel-van-basisregistraties/basisregistratie-grootschalige-topografie. It can also be accessed again via
In addition, the municipality of Amsterdam produces maps of spatial data, published at https://maps.amsterdam.nl. Maps are shown based on data of land use, spatial planning, nature objects, and many others. These maps contain valuable material, and within the PUMA project we will explore the possibilities of using these data.

These databases are already in the right format for both the identification of the relevant appliances and for the location of these appliances. They form a very useful starting point for PUMA and an opportunity for mapping the urban mine.

Ad 3. The second piece of information is the use of metals in these buildings. This is obviously essential information but it may not be directly available, as builders do not generally keep stock of the construction materials they use. There are some examples of studies specifying that for their own cases (Wallsten et al., 2013). At TU Delft, general information is available on the composition of buildings, which is used to support this project.

In cases where this database does not provide sufficient information, estimates are made based on indirect information, such as:

- Building and demolition waste data
- Expert knowledge on general building practice in certain time periods or for certain types of buildings.

A good starting point is constructing a list of metal applications in buildings. These include:

- The use of metals in the casco. This refers mainly to steel used in bars and beams, or used to reinforce concrete
- The use of metals on the surface. This refers to lead and zinc, and sometimes copper.
- The use of metals in door- and window frames. This refers mainly to aluminium.
- The use of metals in gutters and pipes on the outside. This is mainly zinc.
- The use of metals in water and sewage pipes on the inside. This refers to copper, lead and steel.
- Heating systems, boilers, geysers and suchlike: this will be mainly steel
- Wiring and cables related to electricity and communication: mainly copper

These will be different for each building. Even if data would be available for each building, it would be a huge job, far beyond the scope of the PUMA project, to collect these data per address or per building and use that to provide a geological map. Therefore, in the PUMA project we have to take a shortcut and try to generalise to a metal content data based on the type and age of building. For example, for the old houses in the city centre, no concrete was used and therefore there will be no steel in the casco. New houses often do not use metal but PVC for their gutters and pipes. Lead in waterpipes will only be found in old, not renovated buildings. In the 1990s, aluminium window frames became mainstream. Based on such generalisations, it is possible to define types of buildings and add general data on metals to those. The per dwelling or per building data are translated into metal contents per square meter of floor surface area. With help of the BAG information, it is then possible to locate the different types of buildings as a step towards translating the information into a map. TU Delft has reported on this in their deliverable (Koutamanis et al., 2016).

Ad 4. The life time distribution of the stock of buildings is available via the BAG and related databases as mentioned above. The life span itself is a more complicated affair. It will be different for
residential and commercial buildings. It will be different for the different neighbourhoods of the city of Amsterdam. The actual life span may differ considerably from the potential life span, or the planned life span. Rough assumptions must be made on that in order to arrive at an estimate of the amount of copper, aluminium and steel that will become available from the urban mine. An overview of the urban planning agenda of the Amsterdam municipality will help to estimate when the metals may become available. Presumably the old centre of Amsterdam is irrelevant as an urban mine as these buildings belong to protected views. Industrial areas, but also more recently constructed residential areas will be more relevant. The schedule for renovation and break down of such areas is crucial information.

II.2 The result: map and database of the urban mine of Amsterdam

The method as outlined above leads to a “geological” map of the urban mine of Amsterdam: a map containing the information about the amounts, the concentration, the accessibility and the location of the secondary “deposits”. The value of this map is to show that it is possible and also valuable to regard the city with a geologist’s eye, as a potential source of materials. Waag Society has constructed maps using the method outlined in the previous chapter. The maps are available at http://code.waag.org/puma/. Because of the high uncertainties in the metal contents of buildings, there are two maps for each metal, representing the lower and higher boundaries of the estimates. We were unable to provide meaningful estimates for aluminium as this metal is not standardly used in any construction application – the only way to assess this would have been by actually visiting each building. For copper and steel, we succeeded. Below in Figure 2 we show some fragments of the maps for copper and steel.

Figure 2 Fragments of the maps representing the urban mine for copper (blue) and steel (red). Lighter colors represent higher metal contents.

As part of the pilot function of the PUMA project, Metabolic has done a ground truth check by visiting different types of buildings. One aim of that check is to validate the assumptions made by TU Delft on metal contents of buildings. A second aim is to establish whether it would be possible to obtain data on metals on the per address level. If so, we could see our way forward to a much larger future project to build a stock database for cities in general. The report of this ground truth check is available as a deliverable of this project (Blok & Roemers, 2016).
The data shown on the maps is available via the projects’ GitHub repository at https://github.com/waagsociety/puma/tree/master/data. This folder contains three files. The article by Koutamanis et al. (2016) calculates the density of metals in points per address. To visualize this on a map, the values have to be calculated per building. Files are available showing points and associated range of kilograms per address, footprint in square meter, metal content per building and metal content per square meter per building. In addition a file gives the total amount of metals (in kilogram) per Amsterdam borough.

It appears that the urban mine of residential buildings in Amsterdam contains considerable stocks of steel and copper. For steel, the stock is in the order of magnitude of millions of tons, for copper hundreds of thousands of tons, representing a value of hundreds to thousands of million Euro. This large stock is, obviously, not immediately available for mining, since it is presently in use. In the next part, we explore some ideas for creating an urban mining system to access these stocks.
Part III  Exploring options to exploit the urban mine of Amsterdam

III.1   Exploiting the urban mine: some considerations

The second deliverable of the PUMA project is a preliminary urban mining plan. This plan uses the information as described above to make an estimate of the amount of materials that may become available over time, as well as an estimate of the activities needed to actually mine those materials. It is important to show a business case that includes not just a calculation of costs and proceeds, but also practical options for realising secondary production as well as a regulatory context. Various aspects are relevant here as well.

In the first place, what does urban mining look like? As an urban mining system does not exist yet, this is not obvious. Ultimately, it depends on our definition of urban mining. If this is confined to existing waste deposits, complications are probably limited. But if it includes, as is our point of view, also stocks-in-use it is more complicated. It is not possible and also not desirable to extract materials from stocks that are actually being used. But it is possible to adjust the planning to the expected outflows of waste materials out of these stocks. For stocks in use, it is very important to use information on life spans and life span distribution to support such expectations, preferably by using a dynamic stock model.

When and where materials become obsolete, they must be collected and sorted into products that can be reused, materials that can be recycled and unusable waste. Then they will go into some sort of processing, probably mainly recycling processes to transform the waste into good quality materials again and put them on the market. This requires organisation. Questions relate to the actors in the urban mining system, but also to the scale level. Often, it is assumed that urban mining is a local affair. However it may be more efficient to not confine thinking to the local level. Recycling plants will be large undertakings that could handle waste materials from a much wider area. Once the metals are processed into secondary materials, they will be sold on the market, which is basically a world market.

For metals, and probably for many other materials as well, the development of some sort of a local self-sufficient economy is not likely to happen. Nor is it desirable, as it would imply having mining operations within cities and processes that cannot be optimised.

A second question is, who are stakeholders in the value chain? Again, this is not obvious. If we look at who are stakeholders in the presently ongoing recycling business, it is mainly demolishing companies and scrap dealers who buy and sell second hand materials. After that, the materials will probably be sold to primary or secondary producers of metals. In Amsterdam, the AEB (Amsterdam Waste-to-Energy company) also plays a role as they collect metals from household waste, however, this is not related to buildings. An obvious difference between a recycling system and an urban mining system is the aspect of planning. The Amsterdam municipality has a central role in that as an urban planner.

A third issue is the design, establishment and maintenance of the necessary urban mining information
system. The database as described above is a first start of that. An obvious candidate would again be the municipality. In addition, we may envisage brokerage companies as intermediates and owners of information. We also may envisage organisations becoming involved in the setting up and storing of material passports for new buildings. Such passports can be the basis of a future urban mining database. These do not exist yet, but again we could envisage they could become mandatory on the long run. For the present, we have to supplement that with information we collect after the fact, such as provided in the first PUMA deliverable. It is also possible to use geological exploration techniques to estimate the urban mine. This may be especially relevant for underground stocks of cables and pipes.

A fourth, obviously very relevant issue relates to costs. Some very rough estimates will have to serve here for a first indication of the circumstances under which urban mining could be a viable undertaking. Not just data, but also models will be required to support such a mining plan. One of the main obvious differences between a “classic” mine and an urban mine is the fact that the urban mine replenishes itself. Any mining activity therefore does not have to stop with the exhaustion of the mine. Because of this, the urban mine may also change its composition over time. This makes it more difficult to plan activities in the long run. On the other hand, it could also be steered by (municipal) policies related to the choice of construction materials. Related to that are questions of ownership and responsibility throughout the chain. Who owns the materials, who invests in databases and sorting and recycling processes, who pays when the endeavour is (temporarily) unprofitable, who reaps the benefits?

A final issue refers to policies and legislation. As a starting point, urban mining will probably be part of waste policies and legislations. This is related to strict demands and requirements. There are countless examples that these can prove to be a barrier to the set-up of such systems.

In the PUMA project, we address these issues only superficially. We explore a few options of how to set up such systems. These explorations are quite limited. We hope the PUMA project will be a first step and may guide further R&D in this field.

### III.2 Scenarios for urban mining in Amsterdam

It is very likely that, sooner or later, we will move towards some type of urban mining system. Society develops towards a more careful use of resources. Many aspects are still uncertain, and at the moment there is little idea on how to develop urban mining into business as usual. This will depend on many variables, and there probably will be some different models on how to shape such a system. We may face a future with ongoing globalisation, but it is also possible that a more local focus will emerge. Markets can be dominating developments, but it is also possible that policy will have a larger role in such events. It is very difficult to make predictions, or even forecasts. We can circumvent that difficulty by doing a scenario-exercise, not aiming at accurately predicting the future, but at exploring different options, and under each of these options develop some rough ideas of what an urban mining system could look like.

We defined four scenarios based on two axes:

- Scale level: local to global
- Driving force: markets or governments
The scenarios are shown in the table below.

<table>
<thead>
<tr>
<th>Scenario Local Government</th>
<th>Scenario Global Government</th>
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<tr>
<td>Government is dominant over market: policy is driving force</td>
<td>Government is dominant over market: policy is driving force</td>
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<tr>
<td>Most important level of decision making is local</td>
<td>Most important level of decision making is national / supranational / global</td>
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<tr>
<td>Scenario Local Markets</td>
<td>Scenario Global Markets</td>
</tr>
<tr>
<td>Market is dominant over government: market is driving force</td>
<td>Market is dominant over government: market is driving force</td>
</tr>
<tr>
<td>Most important level of decision making is local</td>
<td>Most important level of decision making is national / supranational / global</td>
</tr>
</tbody>
</table>

These scenarios were explored in a workshop with participants from (potential) stakeholders and academia. Minutes of the workshop are available in a separate document. The aim of the workshop was to brainstorm about requirements and characteristics of a successful urban mining system, to obtain insight in opportunities, threats, potentials and difficulties of such a system under various circumstances.

The aspects mentioned in the text were explored by the workshop participants:

- Who are actors in an urban mining system?
- What is the supply chain, who are stakeholders in that chain and what are their interests?
- What does an urban mining information system look like: what data are collected, who collects those data and who maintains the database?
- What are costs and benefits of an urban mining system? Who pays and who makes money?
- What are barriers in the policy system and how can they be removed? How can incentives be built in?

These aspects are explored below for the four scenarios.

**Scenario Local Government**

Urban mining has a strong local component: the urban mines themselves are situated locally and will grow and decline locally as well. Cities and towns are concentrations of materials. Relevant actors at the local level are:

- Municipalities
- Housing corporations
- Other home owners
- Demolition companies
- Waste managers
Municipal policy is the driving force in this scenario, starting from the presence of urban mines and their becoming available at local level. There is a certain logic therefore that an information system should be implemented and maintained under the responsibility of municipalities. Housing corporations and other home owners are, for residential buildings, also the owners of the urban mine. Materials can be extracted from the urban mine of residential buildings at several moments, especially in cases of refurbishing and renovation, and when buildings are demolished. In case of renovation the ownership does not change. Demolition destroys the stock and leaves the materials to other owners: demolition companies. These companies either hand over the materials to waste managers or sell it to scrap traders. After that, the supply chain becomes regional, national or even global as scrap is traded, smelted and put on the market again as secondary materials.

As mentioned before, 95% of demolition waste is already recycled. Still, this can be optimized further by some local level initiatives:

- By having a larger reach: involving not just the municipality but the whole Metropole Region Amsterdam (MRA) can make collection and even processing more efficient;
- Creating a more stable situation in analogy to the flower auction, where auctioneers, exporters and producers work together to strengthen their connection with retailers, better plan the sales and create larger margins of profit;
- Digitalise municipal permit procedures so information is available on planned renovation and refurbishing activities;
- Enable planning in an environment of changing material requirements for the built environment.

The added value of urban mining over "just" recycling is the planning element: instead of being reactive, it is possible to be proactive once knowledge is available about the location and amounts of materials in the urban mine, insight in supply chains, insight in the planning of relevant activities and in construction and demolition plans for the municipality. The local level is important for this type of knowledge, and local governments can play an essential role in it.

**Scenario Local Markets**

In this scenario, driving forces for urban mining are still local but are driven by markets rather than governments. Presently, local markets do not show urban mining initiatives. This implies that incentives are missing or barriers are in place that should be removed. A very important prerequisite is that, in order for companies to jump into the market, urban mining should be a profitable business. Experience shows that for some materials this is sometimes the case – the frequently occurring copper thefts impeding public transport are the proof of that. In general, however, scrap prices are fluctuating, which means that markets are unstable. Also, there is a perverse incentive that by bringing more materials on the market, prices will drop. For local markets to operate in the urban mining business, urban mining should at least be less expensive than primary production from geological mines. The only higher-level governmental policy needed in this scenario is a policy aiming at internalizing external costs, for example by issuing a resource tax or a carbon tax that will benefit secondary production over the energy intensive primary production.
If this policy is in place, many things will change as a result of local business:

- Different types of ownership: “habitation” as a service, linked to producer responsibility
- Different construction business models, such as design for demolition, modular building and other changes in the design of buildings that enable easily taking apart the building after its useful life is over
- Life span reduction instead of life span increase, enabling a lighter construction style and a speedier penetration of innovations in the built environment, such as for example 3D printing of buildings.

In this scenario, a materials market place is essential. This can be organised at the local level to supply local agents, but must be connected to the global market for a better harmonization of supply and demand.

The local information system will be built up via the Building Information Model, a standardised set of information that each constructor needs to fill in. The BIM registration could be stored at the statistics office of municipalities, but in a local markets scenario it might also be stored by a company making money out of providing BIM services to building companies.

**Scenario Global Markets**

The urban mine is always located somewhere, and is therefore local. However, mining companies are not local. Mining companies extend their interest to all relevant places in the world, being places where metal concentrations are sufficient to mine and preferably places that are not too costly or difficult to mine. The difficulty is not just technical but also procedural: permits must be obtained, which sometimes takes a very long time. Once established, mines produce for the world market. The market pull, in the case of metals, therefore is global. Once we leave the idea behind that urban mining should be managed by local organization or companies, we can see that this global market pull can apply to secondary as well as primary materials, and the scale and therefore relevance of business operation increases considerably.

In this market-conform scenario also a shift is foreseen from home ownership to a situation of habitation as a service provided by companies. Especially because of the larger scale level there is a need for an organization responsible for supply chain management. Also because of the larger scale level, there is an opportunity to set this up professionally and efficiently, for example by forming a consortium of bankers, pension funds and other investors with producers and suppliers. This consortium also could take responsibility for the information system, including building passports but also a “tracking-and-tracing” system following the materials through the supply chain.

In this scenario, too, the shift from product to service may lead to design for demolition and modular building. The larger scale level accommodates two types of circularity:

- Re-use of modularly designed building parts at the local level
- Recycling of materials such as metals at the global level.

It can be expected that the main demand for construction materials will occur in the emerging and developing economies, while in developed countries with their ageing populations there will be a large supply of secondary materials that cannot be sold locally. In this way, the “old” economies can become producers for the emerging economies, and material production will no longer be first and
foremost primary production.

**Scenario Global Government**

In this scenario, the developments in Europe will be determined by an EU Framework Directive Raw Materials Supply, where circular economy principles are embedded as a binding directive for national policies. This could result in a system of targets for re-use and recycling. Another consequence could be the emergence of a system of subsidies and taxes to encourage secondary production.

In this scenario there is a need for a supply chain manager as well. In this case, national governments might provide this, for example an innovated “Bouw- en Woningtoezicht” (construction and housing monitoring agency). This organization hosts and manages the information system, that is linked to the cadastral registry, and to the BIM.

Construction permits are being granted based on a grave-to-grave plan. The stock of housing is maintained by renovation. New buildings are constructed only when absolutely necessary. This means the life span of buildings is lengthened, not shortened as in both Market scenarios.

When at last demolition takes place, the secondary materials are traded via marketplaces where the government acts as auctioneer. The information on origins and composition of construction materials and building elements will be linked to a labelling system: a material / product passport. Project developers develop into stock managers.

**III.3 Conclusions from the scenario exercise**

Considering the specific urban mine that is the subject of PUMA – metals in residential buildings - some characteristics of the system are important as a starting point. First, we have established that the stock of metals is large, but the life span of the applications is long and therefore this stock will become available slowly, in small amounts at a time and over a considerable period. Secondly, 95% of the demolition waste is recycled already presently. These characteristics in fact limit the potential effectiveness of additional efforts – it is likely that for other types of stocks there is more to gain.

Nevertheless, the largest stock of metals is still to be found in residential buildings, and the scenario exercise has shown that making a mining plan for these stocks may have added value.

The scenarios lead to specific recommendations that depend on the scale level and the policy intensity. However there are two very important issues that emerge in all scenarios.

The first refers to the information system. In all scenarios, the loss of information through the supply chain about materials used in construction and their composition is identified as a problem, and in all scenarios the need is expressed to maintain the information and make it available. Linked to that, in all scenarios the need is expressed for a supply chain manager, who is responsible for the information system as well as for making it available through the supply chain. In all scenarios, the BIM system is mentioned as a good starting point to store the information, linked to a buildings passport as a tool.

The second issue is the present lack of incentives for urban mining. In each scenario the need is expressed to create incentives, either via the market or via policy, to turn secondary production into a profitable business. Without such incentives, it is unlikely that urban mining systems will be
Incentives can be created either via market mechanisms or via rules and regulations. The market scenarios prefer market conform incentives, such as a resource tax or a carbon tax. Such taxes shift the balance between primary and secondary production and create a more stable basis for secondary material markets. Once the business is profitable, it will establish itself. The policy scenarios explore possibilities of regulation, all the way down from EU framework directives via national targets on recycling to local level permits. Although it is possible to use both types of policy at the same time, it might be advisable to make sure they are not counteracting each other. To some extent, these strategies seem to work in a different direction: in the policy scenarios the system seems to shift towards longer time spans and keeping the stocks in use, while in the market scenarios a development is expected toward shorter life spans and leaner, modular styles of construction. Both may have their merits, it is not beforehand clear which one works better from a circular economy point of view – lengthening life span reduces the inflow, whereas modular and lean building increases reuse and recycling rates. In any case, we have to consider the fact that new construction styles will penetrate slowly and gradually and the present urban mine is different. An urban mining system should in any case allow for the present situation, or it will become relevant only after decades.

The scale level of incentives also leads to some interesting differences. It is clear that the urban mining system has both local and global aspects. The urban mine and what comes out of it is local, but the market for metals and scrap is global. While it makes sense to have local actors involved in collection, repair, renovation and refurbishment, we have to conclude that recycling and secondary production cannot be managed locally. Ideas of closing cycles at the local level will not work and will be counterproductive: supply and demand do not match and it is not feasible to have smelters in each municipality. In the Global Markets scenario a picture is painted of a global mismatch of supply and demand: demand will grow in developing countries while there may be an oversupply in “old” economies. This implies that recycling systems may better be internationally oriented.

With regard to the information system, it is clear that detailed and therefore local information is needed. Local agents, either municipalities or dedicated companies, are indicated to collect this information and build up the database in a bottom-up model, linked to the BIM system. However, to enable policy and business on a higher scale level, a national or even supranational level information system must exist as well. This could be obtained by linking up all local level systems. That would imply all local level systems have to be built up in the same way, using the same parameters and if possible the same underlying databases. For The Netherlands, it is easily possible to upscale the PUMA method as BAG, AHN and other supporting databases are available at the national level and construction styles vary little, relatively. Upscaling to the EU or even global level is of course much more difficult. There may be possibilities to harmonise systems within the EU, a potentially very relevant but probably long term endeavour. At higher scale levels, however, less detail is required and simpler systems may be constructed, either bottom-up or top-down.

Urban mining research is still in its first stages. Presently, making inventories appears to be the main activity and databases are created for different types of stocks-in-use. Residential buildings contain a very large stock of metals, but other stocks are investigated as well and must be included in an urban mining system. Commercial buildings usually contain more metals (especially steel) and usually have a shorter life span. Infrastructure is a large stock, but also liable to leave in hibernation, so may be an easily accessible stock. Machinery, vehicles and consumer appliances also contain considerable amounts of metals and have much shorter life spans. Presently, the information base also for these applications is growing rapidly.
The question on how to arrange and implement urban mining is even less addressed in research. We see some practical efforts emerging, mainly at the local level and aiming at new businesses. It appears from our scenario exercise that global and local aspects are both relevant for urban mining, and that a more comprehensive policy approach is indicated. Together with the emerging interest in resource scenarios, an exploration of policy options could have an impressive added value.
IV References

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