Urban Mining

A Contribution to Reindustrializing the City

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Today's most advanced societies are service-oriented economies. The main resources of such societies are knowledge and information created by and embedded in people and institutions. Classical resources, such as materials, energy, and land, are of less value for service-oriented societies.

Nevertheless, even if one acknowledges the primary role of intellectual resources, material resources are still the backbone of all societies. We cannot pursue our daily activities without the provision of cement, steel, aluminum, cellulose, polyethylene, linear alky benzene sulfonates, and many other materials. Given the high volatility of resource prices and the still heavy pollution of primary production, recycling becomes mandatory. A new approach toward recycling is "urban mining." The term denotes the systematic reuse of anthropogenic materials from urban areas. It is based on the fact that large stocks of materials are incorporated into cities, in particular in buildings and infrastructure but also in landfills. These stocks represent a large resource potential that will eventually—at the end of the product lifetime—become available for reuse. There is no general definition for urban mining yet: Whereas some researchers use the term to describe exploitation of resources from landfills, others apply it to traditional recycling schemes of waste materials, such as construction debris, scrap iron, plastics, or glass. The purpose of the present column is to introduce a more comprehensive interpretation of urban mining. I incorporate two additional aspects—creating a goal-oriented knowledge base by preserving information from production through recovery, and locating recycling facilities within service-oriented cities—to develop the concept into a new strategy to increase the sustainability of the urban metabolism.

Megacities can produce sufficient amounts of secondary resources for large-scale production of raw materials by urban mining, and cities are always in need of energy. Thus, combining recycling plants for metals such as iron, aluminum, and copper in cities with utilization of waste energy from such plants to fuel the city (heating and cooling, electricity) seems an attractive option for improving the sustainability of cities.

First, to facilitate effective urban mining, we require comprehensive information about materials and substances. For the exploitation of primary ores, intrinsic properties, such as element concentration, abundance, availability, speciation, and partner minerals, determine whether a particular substance can be economically mined. The same applies to the recovery of substances from urban material flows and stocks. For example, for the effective recovery of aluminum, one must know whether it is present as solid metallic aluminum (Al) in a car body or building part, as kaolin ($Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$) in newsprint, or as aluminum hydroxide $Al(OH)_3$ in antacids. Depending on how it is used, it can be recovered economically or will be "lost forever." Thus, the information necessary for decisions about urban

DOI: 10.1111/j.1530-9290.2011.00345.x

Volume 15, Number 3

mining comprises all relevant flows and stocks of a particular substance, from production to utilization and disposal at the end of the lifetime. In particular, data about use during the product lifetime are important (location, flows and stocks, density, speciation, partner elements, dissipative losses). This information—a cadaster of secondary resources—forms the basis for determination of priorities for recovery, for design of effective reclamation systems with advanced logistic and recycling technologies, and for environmentally sound final disposal of nonrecyclables. The new knowledge base is necessary to advance from the present state of recycling to a next "urban mining" state, where materials are recovered in a more focused and effective way that takes valuable as well as hazardous substances into account along their path from origin to use phase and final sink.

Second, urban mining not only attends to materials but represents a more comprehensive approach that includes energy. The concept of urban mining to date has not taken into account the question of where recycling takes place. Locating urban mining processes close to the sources of secondary materials and thus within service-oriented urban areas has significant advantages. Transportation of wastes and recyclables requires energy, and so does recycling and processing. Hence, short transport distances and processes with high energy efficiency are mandatory for sustainable urban mining. Urban mining performs best, in view of these criteria, when recycling facilities are located within the city: Megacities can produce sufficient amounts of secondary resources for large-scale production of raw materials by urban mining, and cities are always in need of energy. Utilizing surplus energy from recycling plants for metals such as iron, aluminum, and copper to fuel the city (heating and cooling, electricity) seems an attractive option for improving the sustainability of cities. This relates only to large urban areas populated by several million inhabitants, however, because economy of scale applies to both recycling processes and primary resource extraction. It is noteworthy that the number of cities with more than 10 million inhabitants is abundant and growing (in 1950 there were two such cities, in 1975 there were three, in 2000 there were 18, and in 2015 there will likely be 22; UN 2006).

To establish such a comprehensive "urban mining" strategy, we have to better understand the system "city." In particular, it is important to take into account the different phases of urban development: Most cities grow, some are in a (temporary) steady state, and a few are shrinking. In growing cities, the import of solid materials—essentially construction materials—outweighs the export because of the long lag time between production and disposal (several decades). Today, this is particularly the case for fast-growing Asian cities, where the input-output ratio for solid materials is greater than 10:1. For such cities, recovery of materials from the urban metabolism cannot make significant contributions to meeting demand. Thus, although recycling, for example, of construction wastes is of importance for environmental protection, it does not alleviate the need for primary resources. Conversely, some shrinking regions, such as cities in eastern Germany (Schiller et al. 2010) or in the former Soviet Republics, are in a different situation: Their demand decreased due to population and economic losses, and thus material consumption today is lower than before. Due to a smaller population, part of the aging material stock is not needed anymore and becomes obsolete. Thus, the potential output exceeds the input. For such areas, urban mining strategies seem attractive (and are, in fact, actively practiced: Missing power lines in some industrial urban areas are noticeable examples).

Some cities are close to a steady state: Import and export of materials are in balance. For these mature cities, the urban outputs represent more than a marginal contribution to the resource needs. For them, it is conceivable that a large fraction (more than 80%) of primary resources can be substituted by secondary resources. Due to the difference in composition and speciation, however, not all outputs can be recycled. There will always be a certain need for primary resources as well as for "sinks," such as incinerators, sewage treatment plants, and landfills for nonrecyclable residues of the urban metabolism.

There are more benefits to such an urban mining strategy of bringing industrial processes back into the city than just energy saving and a shorter transport distance. (1) Having potentially polluting recycling facilities inside the city boundaries can prompt the rigorous application of best available technologies (BAT): Several million inhabitants are watching the process on a daily basis, which thus increases the likelihood that environmental standards are strictly observed. A shining example is the Spittelau municipal solid waste incinerator, close to the center of Vienna, designed by Friedensreich Hundertwasser; real-time emissions are presented online on a large public display close to the incinerator. (2) There is a better balance of intangible benefits between the city and its hinterland: Today, the hinterland gets the wastes and pollution from the primary production as well as by recycling, and the city gets the "clean" utility of the resources. (3) The public has a chance to become aware of the large material flows that are associated with modern life. (4) Finally, the city will become less reliant on imported resources by taking advantage of its own secondary resource base.

To facilitate an urban mining strategy, we need to develop a new knowledge base. A general question relates to the information requirements: Which information is needed for setting the right priorities, for planning and implementing appropriate measures, and for ensuring the overall cost-effectiveness of urban mining? Information requirements will extend across many materials and substances and will cover long time periods (e.g., several decades for materials in the urban stock of buildings and infrastructure). Thus, to prevent high costs and little utility, it is of utmost importance to elaborate clear goals and strategies for the new knowledge base.

Data about flows and stocks of materials and substances will play a major role in urban mining. There is already a large and increasing information base about the global, national, and sometimes even regional use of metals (Graedel and Cao 2010). When broken down on the city level and when augmented with information about the possibility to recover these resources, such data will be of high value for urban mining. Additional research is needed to pinpoint the main potentials for recovery: Up to now, researchers have not known whether the major resource potential is in the urban stock, in the landfills of municipal solid waste (MSW) and other wastes, or in the tailings and residues from mining. Finally, economic modeling is needed to clarify which potentials of secondary resources promise an economic benefit and which pose marginal or even negative assets.

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