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Universidad Politécnica de Madrid
ETS de Ingenieros de Minas y Energía

Urban Mining: the way to reach a real sustainability

Jorge Castilla Gómez, PhD
jorge.castilla@upm.es

Madrid School of Mines and Energy
Technical University of Madrid (UPM) - Spain

OMICS International

World Congress and Expo on
Recycling

July 20-22, 2015 TRYP Barcelona Apolo Hotel

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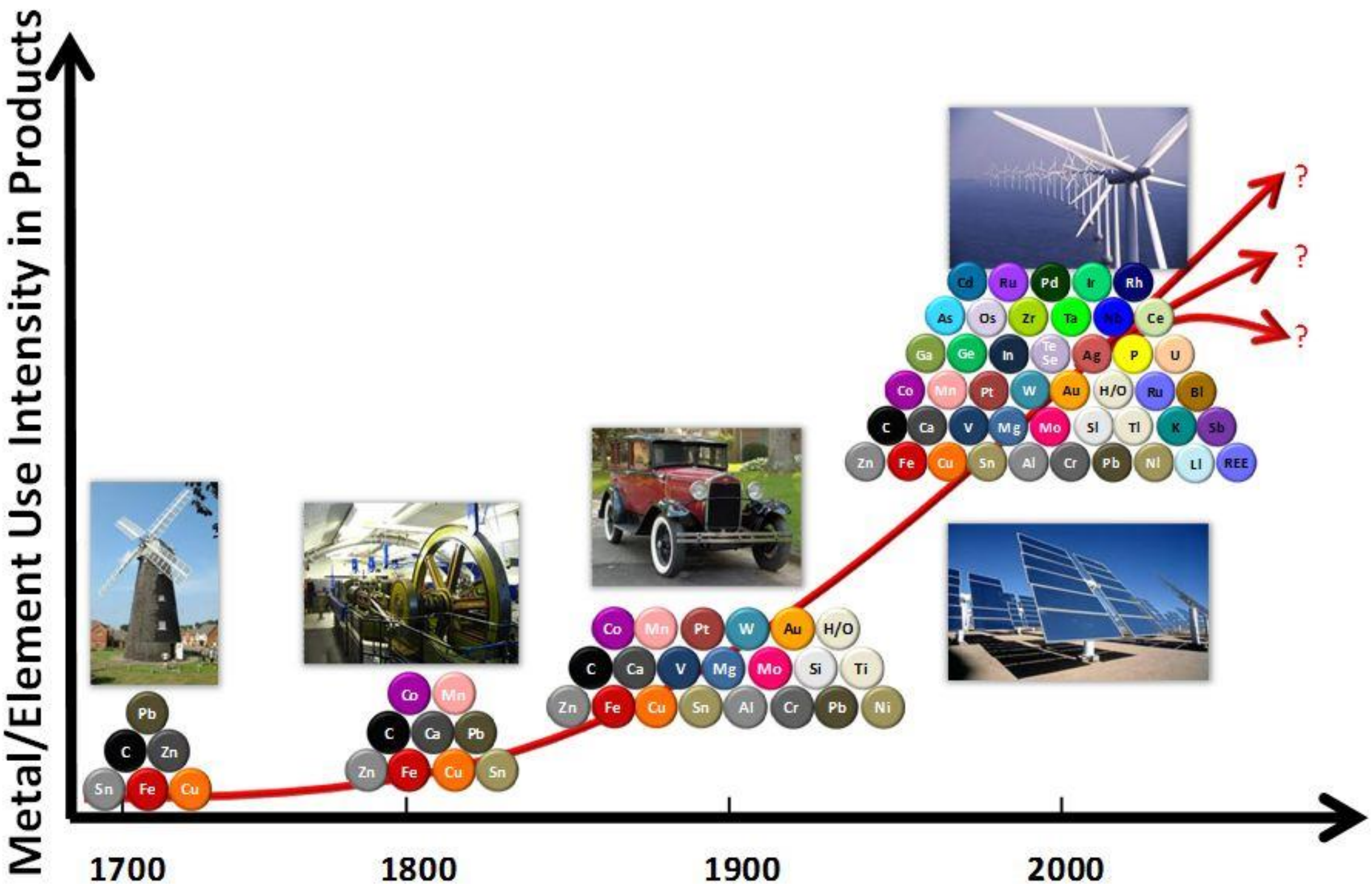
Global demand of raw materials

- Minerals are essential to everyday life, making up numerous products.
- They are also vital raw materials in a large number of industries.
- Since the late 20th century, the decreasing depletion of natural resources due to strong economic growth has become a particularly acute issue.

Global demand of raw materials



Global demand of raw materials

ELEMENTS OF A SMARTPHONE

ELEMENTS COLOUR KEY: ALKALI METAL · ALKALINE EARTH METAL · TRANSITION METAL · GROUP 13 · GROUP 14 · GROUP 15 · GROUP 16 · HALOGEN · LANTHANIDE

SCREEN

49 In Indium · 50 Sn Tin · 8 O Oxygen

Indium tin oxide is a mixture of indium oxide and tin oxide, used in a transparent film in the screen that conducts electricity. This allows the screen to function as a touch screen.

13 Al Aluminium · 14 Si Silicon · 8 O Oxygen · 19 K Potassium

The glass used on the majority of smartphones is an aluminosilicate glass, composed of a mix of alumina (Al_2O_3) and silica (SiO_2). This glass also contains potassium ions, which help to strengthen it.

39 Y Yttrium · 57 La Lanthanum · 65 Tb Terbium · 59 Pr Praseodymium · 63 Eu Europium · 66 Dy Dysprosium · 64 Gd Gadolinium

A variety of Rare Earth Element compounds are used in small quantities to produce the colours in the smartphone's screen. Some compounds are also used to reduce UV light penetration into the phone.

ELECTRONICS

29 Cu Copper · 47 Ag Silver · 79 Au Gold · 73 Ta Tantalum

Copper is used for wiring in the phone, whilst copper, gold and silver are the major metals from which microelectrical components are fashioned. Tantalum is the major component of micro-capacitors.

28 Ni Nickel · 66 Dy Dysprosium · 59 Pr Praseodymium · 65 Tb Terbium · 60 Nd Neodymium · 64 Gd Gadolinium

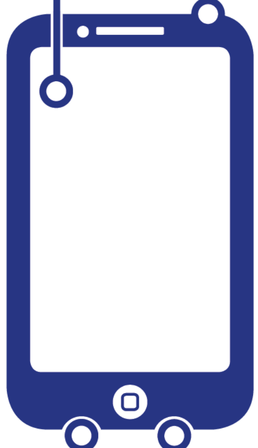
Nickel is used in the microphone as well as for other electrical connections. Alloys including the elements praseodymium, gadolinium and neodymium are used in the magnets in the speaker and microphone. Neodymium, terbium and dysprosium are used in the vibration unit.

14 Si Silicon · 8 O Oxygen · 51 Sb Antimony · 33 As Arsenic · 15 P Phosphorus · 31 Ga Gallium

Pure silicon is used to manufacture the chip in the phone. It is oxidised to produce non-conducting regions, then other elements are added in order to allow the chip to conduct electricity.

50 Sn Tin · 82 Pb Lead

Tin & lead are used to solder electronics in the phone. Newer lead-free solders use a mix of tin, copper and silver.



BATTERY

3 Li Lithium · 27 Co Cobalt · 6 C Carbon · 13 Al Aluminium · 8 O Oxygen

The majority of phones use lithium ion batteries, which are composed of lithium cobalt oxide as a positive electrode and graphite (carbon) as the negative electrode. Some batteries use other metals, such as manganese, in place of cobalt. The battery's casing is made of aluminium.

CASING

6 C Carbon · 12 Mg Magnesium · 35 Br Bromine · 28 Ni Nickel

Magnesium compounds are alloyed to make some phone cases, whilst many are made of plastics. Plastics will also include flame retardant compounds, some of which contain bromine, whilst nickel can be included to reduce electromagnetic interference.

Sustainable Mining

- Definition of **Sustainable Development** (Brundtland):

  "…Development that meets the needs of the present without compromising the ability of future generations to meet their own needs".

- Appropriate management of non-renewable resources extracted by this sector of the economy has been one of the key issues in debates about **sustainability**.

- Reasons include the finite nature of non-renewables; the diverse environmental impacts associated with their extraction and use; the economic importance of the primary extraction; and the social impacts on local communities associated with mining activities.

Sustainable Mining

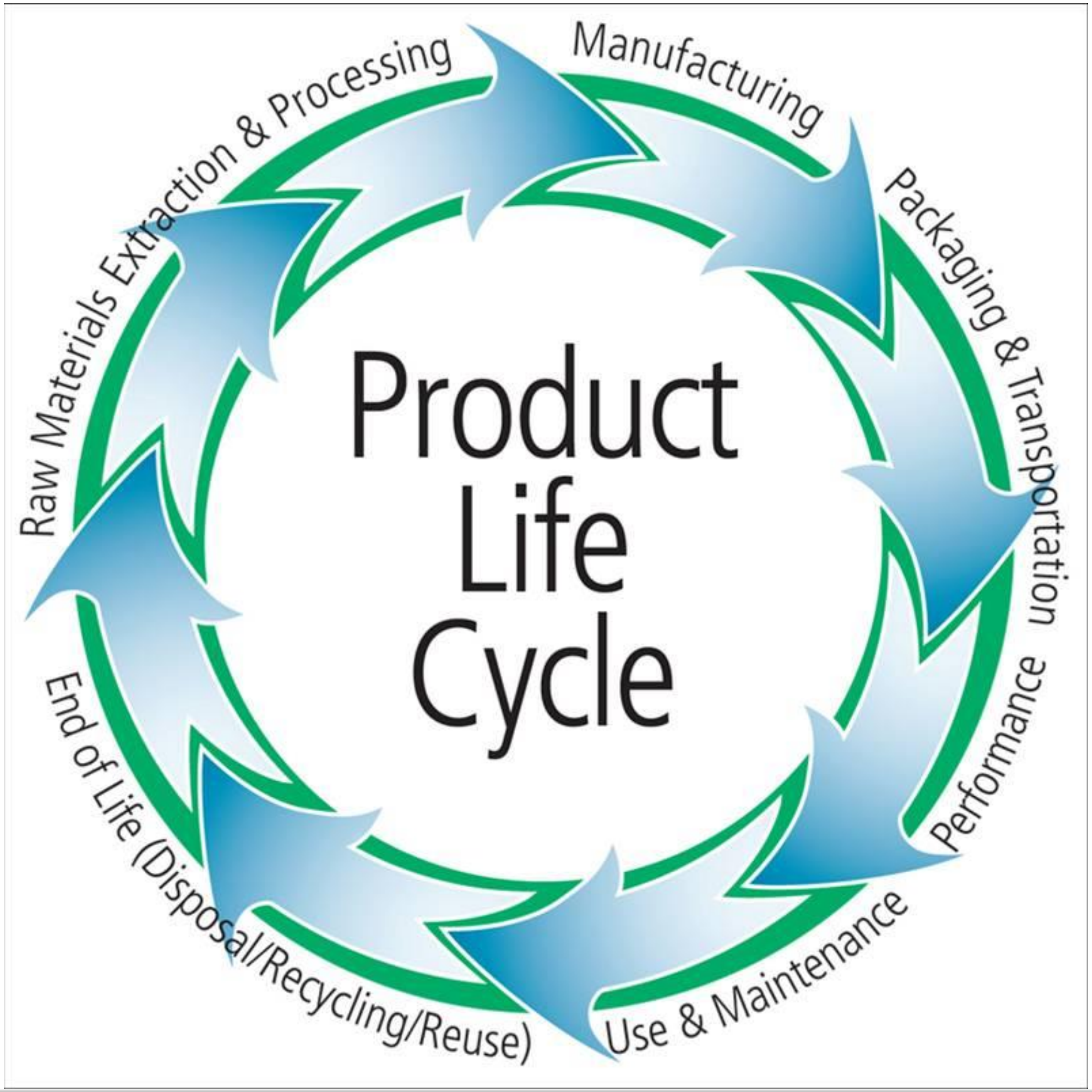
- At first "sustainable mining" could be perceived as a paradox, because minerals are widely held to be finite resources with rising consumption causing pressure on known resources.
- The true sustainability of mineral resources, however, is a much more complex picture and involves exploration, technology, economics, social and environmental issues, and advancing scientific knowledge, predicting future sustainability is therefore not a simple task.
- The context for sustainable development for mining is to balance the potential environmental and social risks with the economic risks.

Sustainable Mining

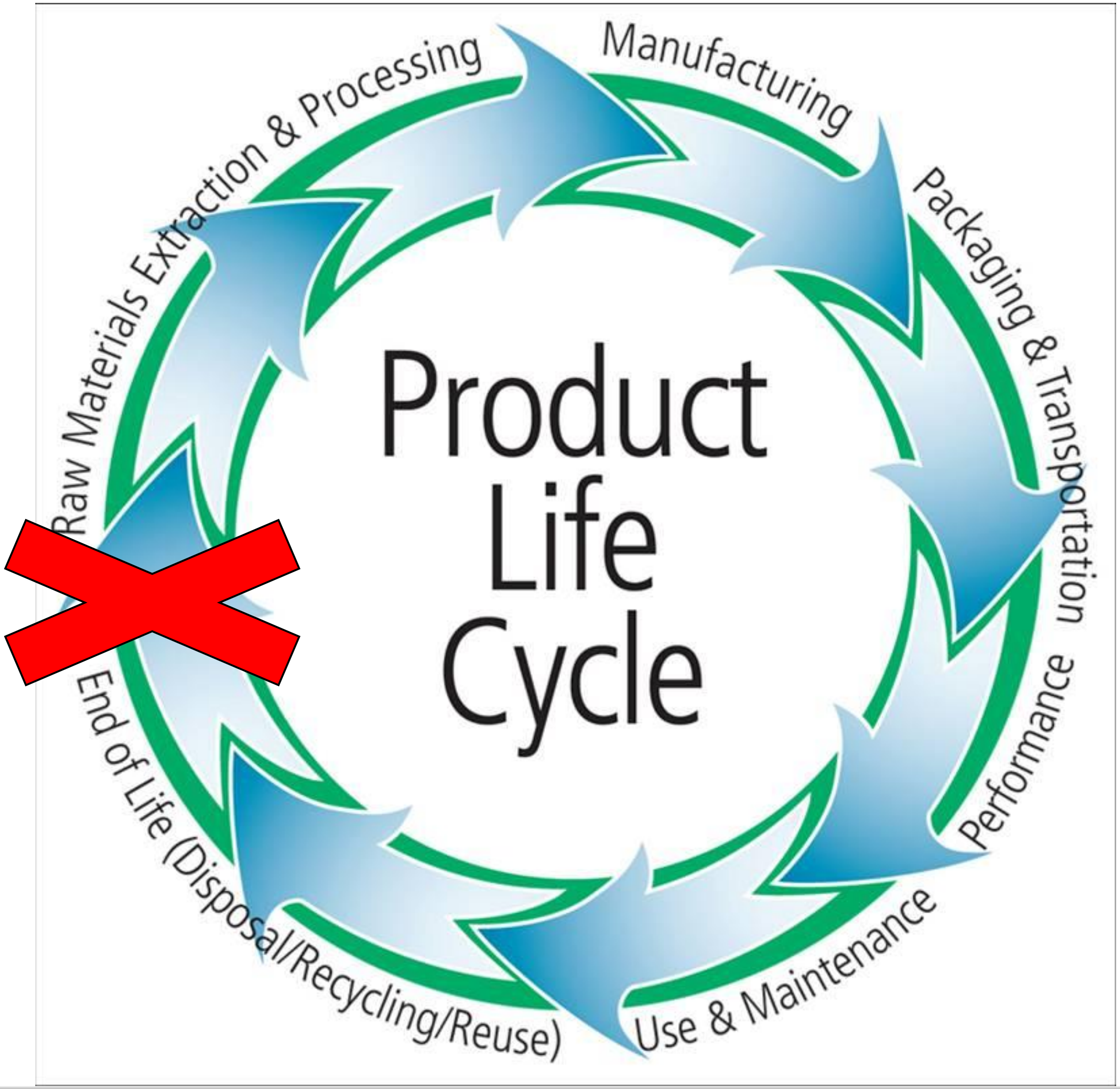
Life cycle Assessment

- Life Cycle Assessment (LCA) is an analytical tool that captures the overall environmental impacts of a product, process or human activity from raw material acquisition, through production and use, to waste management.
- Life cycle assessment (LCA) is an evaluation method that estimates the energy and environmental burden of a process or an activity by identifying and assessing the resources consumed and the emission and waste released in the environment.

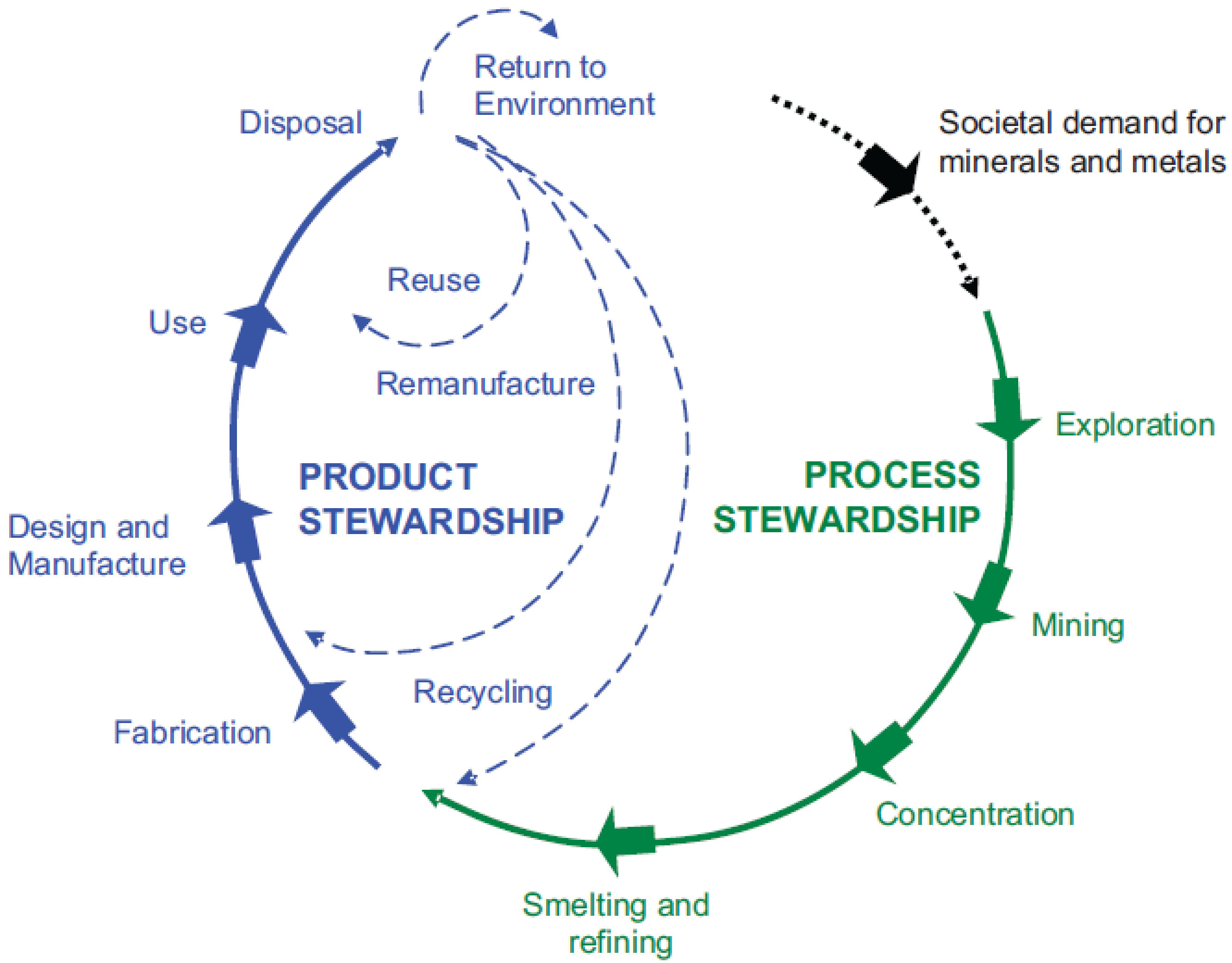
Life cycle Assessment



Life cycle Assessment



Life cycle Assessment



Urban Mining

- The concept of Urban Mining concerns all the activities and processes of reclaiming compounds, energy and elements from products, buildings and waste generated.
- Mining and Recycling are complimentary to secure metal supply for infrastructure and products.

Urban Mining

- Massive shift from geological resources to anthropogenic “deposits”
  - Electric & electronic equipment (EEE)
    - Over 40% of world mine production of copper, tin, antimony, indium, ruthenium & rare earths are annually used in EEE.
  - Mobile phones & computer
    - Account for 4% world mine production of gold and silver and for 20% of palladium & cobalt.
  - Cars
    - >60% of PGM mine production goes into autocatalyst, increasing significance for electronics and light metals.

Urban Mining

- In the last 30 years we extracted >80% of REE, PGM, Ga, In, … that have ever been mined.
- Clean energy technologies & other high tech applications will further accelerate demand for technology metals (precious metals, semicondictors, rare earths, refractory metals,…)
- **Without access to these metals no sustainable development can be achieved.**

Urban Mining

- The Urban Mining “deposits” can be much richer than primary mining ores:

Primary mining
- ~ 5 g/t Au in ore
- Similar for PGMs

Urban mining
- 200 g/t Au, 80 g/t Pd & Cu, Sn, Sb, … in PC motherboards
- 300 g/t Au, 100 g/t Pd … in cell phones
- 2,000 g/t PGM in automotive catalysts

Recycling

- Recycling is considered as core element of the sustainable development.
- To tackle the depletion of natural resources, recycling policies and legislation have been put in place to ensure a sustainable development.
- The recycling industry itself, however, requires inputs of primary resources, which makes its environmental performance dependent on the chemical, physical and thermodynamical limits of the process.

Recycling

Limiting Factors in Recycling

- Collection of recycled material streams
- Limitations are set by nature, such as physics, chemistry, metallurgy and thermodynamics.
- Relationship between quality and recovery of a given metal or metals.
- Products to be recycled must be separated into suitable streams as soon as possible.
- Inevitable losses.

Conclusions / Challenges

- Collection of recycled material streams.
- Limitations are set by nature, such as physics, chemistry, metallurgy and thermodynamics.
- Relationship between quality and recovery of a given metal or metals.
- Products to be recycled must be separated into suitable streams as soon as possible.
- Inevitable losses.
- Recovery and recycling of cell phones are in the early stages of development.

"There are more gold in one tone of iPhones than in one tone on rock."

REFERENCES

- Azapagic A., Developing a framework for sustainable development indicators for the mining and minerals industry. Journal of Cleaner Production, 2004, 12(6), 639-662, http://dx.doi.org/10.1016/S0959-6526(03)00075-1.
- Baccini, P., Brunner, P.H., 2012. Metabolism of the Anthroposphere – Analysis, Evaluation, Design. The MIT press, Massachusetts Institute of Technology, Cambridge, ISBN 978-0-262-01665-0.
- CowellS.J., Wehrmeyer W., Argust P.W., Graham J., Robertson S., Sustainability and the primary extraction industries: theories and practice, Resources Policy 25 (1999) 277–286.
- Curran M.A., Life Cycle Assessment: a review of the methodology and its application to sustainability. Current Opinion in Chemical Engineering, 2013, 2(3), 273-277, http://dx.doi.org/10.1016/j.coche.2013.02.002.
- Di Maria, F., Micale, C., Sordi, A., Cirulli, G., Marionni, M., Urban Mining: Quality and quantity of recyclable and recoverable material mechanically and physically extractable from residual waste. Waste Management, 2013, 33(12), 2594-2599, http://dx.doi.org/10.1016/j.wasman.2013.08.008.
- Fleury A.M., Davies B., Sustainable supply chains—minerals and sustainable development, going beyond the mine. Resources Policy, 2012, 37(2), 175-178, http://dx.doi.org/10.1016/j.resourpol.2012.01.003.
- Jamali-Zghal, N., Lacarrière, B., Le Corre, O., Metallurgical recycling processes: Sustainability ratios and environmental performance assessment. Resources, Conservation and Recycling, 2015, 97, 66-75, http://dx.doi.org/10.1016/j.resconrec.2015.02.010.

REFERENCES

- Laurence D., Establishing a sustainable mining operation: an overview. Journal of Cleaner Production, 2011, 19(2–3), 278-284, http://dx.doi.org/10.1016/j.jclepro.2010.08.019.
- Meskers C., High-Tech recycling of critical metals: Opportunities and challenges. Umicore. 2014.
- Moran, C.J., Lodhia, S., Kunz, N.C., Huisingh, D., Sustainability in mining, minerals and energy: new processes, pathways and human interactions for a cautiously optimistic future. Journal of Cleaner Production, 2014, 84, 1-15, http://dx.doi.org/10.1016/j.jclepro.2014.09.016.
- Mudd G., Global trends in gold mining: Towards quantifying environmental and resource sustainability? Resources Policy, 2007, 32(1-2), 42-56, http://dx.doi.org/10.1016/j.resourpol.2007.05.002.
- Mudd G.M., The Environmental sustainability of mining in Australia: key mega-trends and looming constraints. Resources Policy, 2010, 35(2), 98-115, http://dx.doi.org/10.1016/j.resourpol.2009.12.001.

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