Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 97 (2016) 15 – 22

Energy Procedia

European Geosciences Union General Assembly 2016, EGU
Division Energy, Resources & Environment, ERE

SMART GROUND Project: SMART data collection and inteGRation platform to enhance availability and accessibility of data and infOrmation in the EU territory on SecoNDary Raw Materials

Giovanna Antonella Dino*[,a], Piergiorgio Rossetti [a], Giulio Biglia [a], Frédéric Coulon [b], Diogo Gomes [b], Stuart Wagland [b], Sami Luste [c], Heikki Särkkä [c], Csaba Ver [d], Marco Delafeld [e], Antonietta Pizza [e]

[a]*Università di Torino - Earth Science Department, Via Valperga Caluso, 35 – 10125 Torino, Italy*
[b]*Cranfield University - School of Water, Energy and Environment, Cranfield University, Cranfield, Bedfordshire MK43 0AL*
[c]*Mikkeli University of Applied Sciences, Patteristonkatu 3, P.O. Box 181,50101 Mikkeli, Finland*
[d]*University of Pecs, Hungary*
[e]*ENCO consulting Napoli, Italy*

Abstract

The issue of resource security has come to the forefront of the debate as Critical Materials (CRM) and Raw Materials (RM) supply is fundamental to maintain and develop EU economy. Considering the increasing scarcity and raising prices of RM, their recycling and recovery from anthropogenic deposits is essential. To date there is no homogeneous inventory available of SRM and CRM present in EU landfills, and best management practices to recover SRM from landfill activities are inefficient. In this context, the EU SMART GROUND project intends to foster resource recovery in landfills by improving the availability and the accessibility of data and information on SRM in the EU.

Peer-review under responsibility of the organizing committee of the General Assembly of the European Geosciences Union (EGU)

Keywords: mine waste, municipal solid waste, circular economy, landfill mining, secondary raw materials, critical raw materials

* Corresponding author: tel. +39 011 6705150.
E-mail address: giovanna.dino@unito.it

Peer-review under responsibility of the organizing committee of the General Assembly of the European Geosciences Union (EGU)
doi:10.1016/j.egypro.2016.10.010

1. Introduction

Resource security is now a priority for governments of developed countries. This priority is partly due to considerable concern over the security of supply of the so called 'critical' raw materials (CRM; Fig. 1), with rare earths attracting the greatest attention in the press. Their supply is essential to maintain and develop EU economy as its industries rely on a steady supply of Raw Materials (RM). Most of CRM are exploited in countries other than EU countries (Table 1 and Fig. 2), causing high economic dependence from non-EU countries.

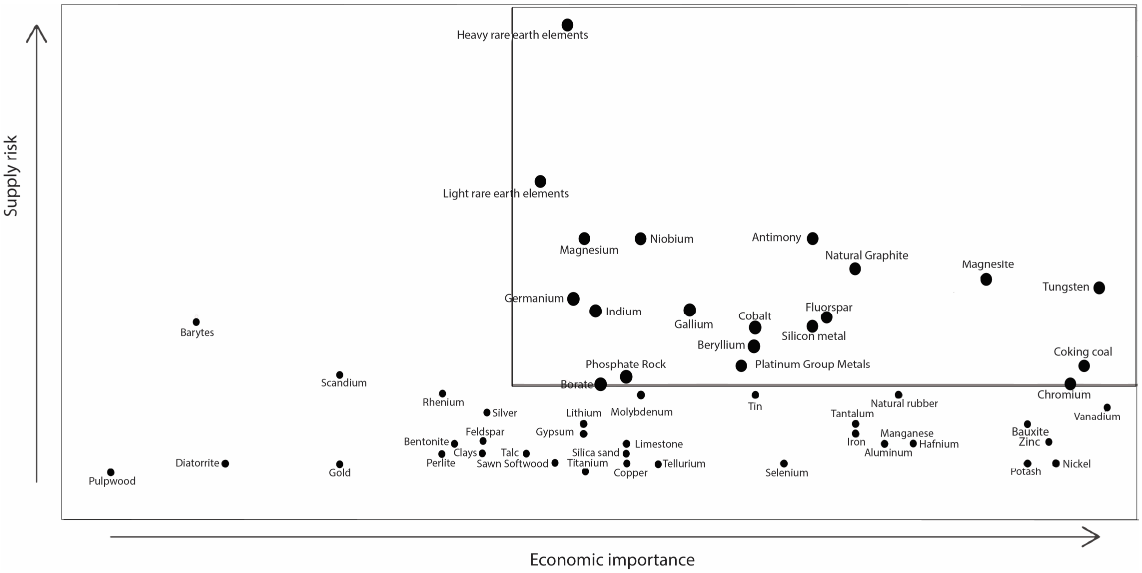

Fig. 1. Economic importance and supplying risk of Raw Materials (EU Commission, 2010)

Table 1: World production of Strategic Raw Materials and Industrial Minerals.

Minerals/Elements	World production 2011 (t)	Change (%) 2011-2007	Main producers - world (%)		EU production – World (%)		Main EU producers	Import to EU (t)
Cobalt	113386	76.56	Congo	66.15	140	0.12	Finland	26500[d]
To-Nb [a]	176648	29.74	Brazil	95.93	-	-	-	Ta: 131 Nb: 19700
Tungsten	82278	48.31	China	84.96	1862		Portugal	5329
Gallium	85	14.86	China	50.59	5	5.88	Hungary	Not given
Germanium	66	22.22	China		-	-	-	31.1
REE[b]	100261	-20.05	China	96.65	-	-	-	17600
PGM[c]	428336	-5.1	RSA	58.50	1536	0.36	Finland	Not given
Graphite	1166197	1.50	China	68.60	7000	6.9	Romania	122000
Fluorspar	7015439	22.50	China	59.87	174903	2.49	Spain	715000
Feldspar	21200000	-0.05	Turkey	28.30	7353000	34.68	Italy	3947

[a] Tantalum and Niobium (or Columbium) concentrates; [b] Rare Earth concentrates; [c] Platinum Group Metals, here given as Pt+Pd+Rh, in kg. [d] gross weight.

Source of production data: World Mining Data 2013, apart from feldspar (USGS 2013). Import data (referred to 2006-2009, depending on the material) are from EC 2010 - Report of the Ad-hoc Working Group on defining critical raw materials. Apart from feldspar, all minerals in the Table belong to the CRM as defined by mentioned EC 2010 Report.

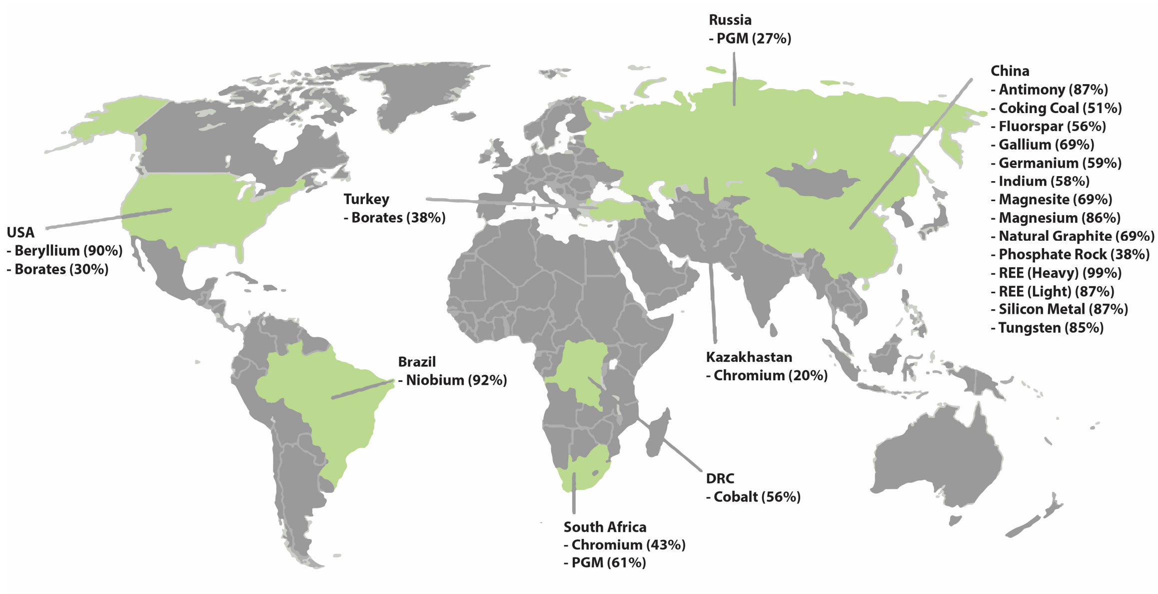

Fig. 2. Production of Critical Raw Materials in the world [1]

The European Initiative Partnership (EIP) on Raw Materials focuses on promoting innovation in two main areas that are now described. Firstly, it aims to promote innovation on technologies that will improve the recovery from waste (e.g. red mud and abandoned or closed mining waste facilities). Secondly, the EIP aims to turn wastes into valuable SRM by developing more efficient recycling/recovering processes (e.g. metals recycling from municipal waste, thermochemical phosphorous recovery from incinerated sludge, rare metals recovery from waste electric and electronic equipment, advanced recycling methods for the construction and demolition waste, multi-material cartons and paper waste). These are two key areas to promote a circular economy.

Furthermore, the European Commission in a 2012 communication stated that more ought to be done to help reduce the landfilling of materials throughout their life cycle [2]. It is thus clear that existing and future policy will support a comprehensive approach to waste management. The Smart Ground (SG) project plays a core role in this comprehensive approach. This paper presents the aims, methods and intended outcomes of the SG project. The next section explains this project within the European and waste management context.

2. Extracting SRM from untapped sources: the 5R hierarchy through landfill mining

There are different estimations for the number of landfills in Europe. Hogland et al. [3] state that in Europe there are 350.000-500.000 landfills. Vossen [4] puts the number at around 150.000 landfills covering approximately 300.000 hectares. EURELCO in 2016 indicates that the total amount of landfills in Europe is most likely even bigger than initially thought, estimating more than 500.000 landfills. Ninety percent of those landfills are in reality non-sanitary landfills, predating the Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste. Moreover, EURELCO states that 80% of Europe's landfills essentially contain municipal solid waste (MSW), while only 20% are landfills containing more specific industrial wastes and residues.

It is vital to think about "waste" as "future resources" and "landfill" as "new ore bodies". An approach such as this allows considering the waste streams disposed in landfills as having potentially recyclable materials. This historical background makes the old waste dumps possible sources of RM. Substituting the word "WASTE" with the word "RESERVE" transforms the 4R hierarchy into 5R hierarchy (Fig. 3). This simple replacement makes it possible to understand the passage from linear economy to circular economy (Fig.4). A circular economy approach is the basis for a re-planning of the industrial processes that minimizes the exploitation of natural resources and reuses/recycles/converts potential waste into resources (for the same or other productive cycles).

The constant recovery of waste (which can be considered as by-products) from processing activities is the tendency for the future. It is already an existing reality in some industries: e.g. some samples from extractive industry [5]. At the same time SRM exploitation from landfill mining has to be enhanced. Both approaches are in line with Reserve Preservation and Waste recycling EU principles (pillars of the H2020 program). The next section presents the SG project and how it aims to contribute to SRM exploitation in Europe.

Fig. 3: Passage from 4R to 5R hierarchy

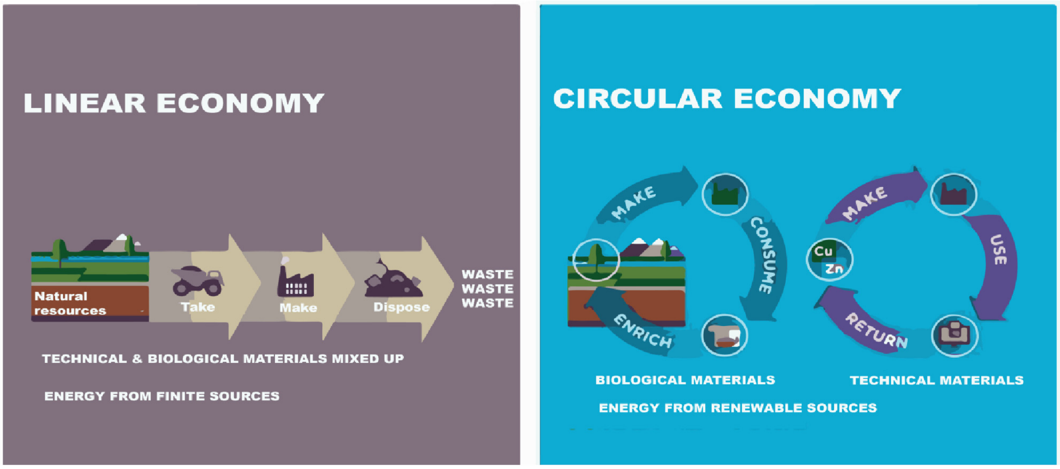

Fig. 4: Passage from linear economy to circular economy [6]

3. Potential across Europe: European inventory and database – the Smart Ground project

To recover SRM and CRM from landfills, it is vital that the knowledge of specific information such as landfill ("new ore body") localization, waste volume, waste characteristics, presence of dressing/treatment plants, impacts, SRM's EU market, be known. This will allow the development of a guideline (best practices) to recover waste from landfill and to recycle it into new products. At present, no data inventory on SRM and CRM in landfills is available at EU level. Several databases (DB) are present at local and national level. Nevertheless, these DB are not always correct as some inaccuracies are found from local to national level. Furthermore, these DB are not collected at EU level. There is some information about MSW landfills, but very scarce information about extractive facility landfills. Also, best management practices to recover SRM from landfill activities are inefficient. Some reports on landfill mining have been published during the last couple of years. Nonetheless, the best possible methods have yet to be identified. Moreover, the information that enables the use of SRMs from landfills has not been made available. The SG project intends to foster resource recovery in landfills by improving the definition of new and integrated data acquisition methods and standards (tested on selected pilot sites). SG is gathering data from existing databases and collecting new information from municipal, industrial and mining waste streams across EU landfills. With this knowledge base, SG is creating synergies among the different stakeholders involved in the SRM value chain. SG faces six main challenges that are now summarized. The first is the creation and maintenance of an online database: SMART GROUND DB (Fig. 5). The second main challenge is the characterization of 15 pilot sites – three for each country involved in the project. Pilots are representative of MSW landfills, mining landfills and industrial landfills. The final three challenges are respectively to achieve a general assessment of EU SRM; to establish communication and dialogue with key stakeholders; to promote coordination and networking between researchers, entrepreneurs and public authorities at national and EU level.

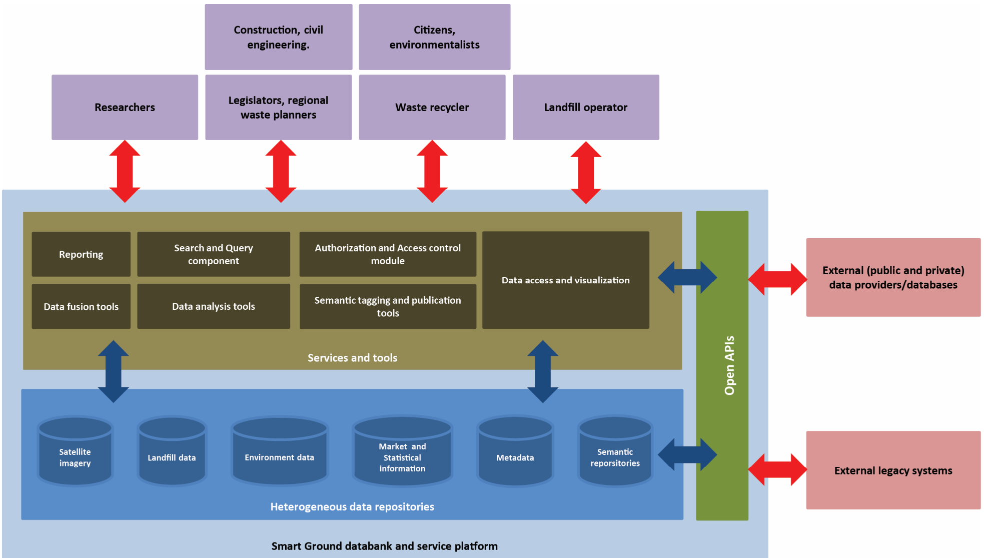

Fig. 5: Smart Ground Data Base Conceptual model

In general, a different approach to waste management and recovery has to be forecasted ("mining approach"). Several actions are core if we want to exploit a landfill/dump as a new ore body. We need to analyze the geopolitical, environmental, economic and social context. This makes it possible to evaluate if exploitation of the resources present in landfills/dumps is feasible.

At this stage it is essential to collect information, at local, national and European scale. The accuracy level of the information collected varies from local to EU level, depending on existent DB, research projects and practices. Furthermore, maps of RM potential (local, national and EU scale) are central to program for RM supply.

To exploit landfill/ore-body specific information is needed. In the pilots, that are going to be analyzed in this project, the specific information collected is the following:

a. Study of the landfill/ore body characteristics and of the exploitable materials:
   - Localization (where is the landfill/dumping area? Is it easy to access? Etc.)
   - Landfill/dump volume
   - Waste/resource characteristics (chemical, physical, mineralogical, mechanical, etc.). This is will be carried out through a prospecting activity
   - In case of facilities from extractive industries, the geological setting is fundamental

b. Evaluation of which RM, SRM and/or associated minerals/elements present in the "ore body"

c. Evaluation of RM, SRM and/or associated minerals/elements content in the whole exploitable volume

d. Evaluation of RM, SRM and/or associated minerals/elements content in specific classes (due to size distribution, specific treatment as magnetic separation, hydrogravimetric separation, air classification, floatation, etc.); in these cases dressing plant pilots have to be forecasted

e. Study of any particular restriction in accessing and exploiting the investigated area (landscape restriction, environmental restriction, natural park area, etc.)

f. Study of local policy and legislation as for RM exploitation and waste management

g. If a planning activity in waste management was forecasted, a study of the distribution of RM, SRM and/or associated minerals/elements will be carried out

h. Evaluation of the best technologies and methods for "ore body" exploitation

The next section presents how the SG project will analyze the SRM recovery potential of extractive industry.

4. First consideration about SRM recovery from landfill: e.g. extractive industry

In the mining context, the project will obtain data of former and current mining sites. It will also find out if it is possible to recover the waste stored on these sites as SRMs. The member states have to carry out and periodically update an inventory of closed waste facilities which cause or have the potential to cause a serious threat to human health or the environment. Such inventory at local/national scale, depending on local authorities, provides information such as: localization; volume; characteristics (e.g. analysis, mapping); impacts; private company enrolled in mining activity; period. At EU level, the information is often not complete or not accessible. Moreover, information is focused on environmental impacts and not on the characteristics of the materials present in landfills. The recovery of extractive waste, by means of recycling, reusing or reclaiming, is encouraged by the directive. Nevertheless, such kind of recovery on old landfills is mostly inefficient because of the lack of data. Moreover, there are policy short comes because several services are involved in the extractive industry. These services and respective policies are not coordinated at local and national levels.

In modern mines, technological advances and changes in regulations have resulted in significant changes in waste management practices over the last 10 to 20 years. Mine wastes are generally better managed than they have been in the past [7]. Waste management plans are frequently developed before a mine is constructed. Moreover, the reclamation of waste rock dumps and tailings ponds are increasingly incorporated into the designs of new mines. In addition, in many parts of the world authorities require a proper waste management plan before issuing a mining permit [8].

Extractive industry, waste recovery and recycling have been investigated by several studies (scientific papers, funded projects). These recognize three main waste categories: rock waste, operating residues and tailings. If the waste is managed separately, the landfills can be considered as “mono-waste” landfills and properly exploitable for SRM production. This will depend on the specific characteristics of the ore bodies and/or the treatment (dressing/working) plant.

As for rock waste and residues (both from mine and from treatment plant), it is essential to separate different fractions (from coarser to finer). This separation allows evaluating the potential recovery of each of them. Such fractions can be recovered as:

- aggregate (if poor in valuable minerals) [9, 10, 11, 12, 13, 14];
- industrial minerals [5, 15];
- valuable SRM from operating residues (metals and elements associated to first RM; e.g. PGE to nickel deposits, Ga-Ge-In, etc. to Zn-Pb deposits, etc.; and sometimes also the first RM, e.g. Zn, Pb, etc. where the selection in the mine yard was not completed or correct).

As for tailings (and sludge at large), which can be rich in contaminants, they are currently used as backfill in underground mines, stored in open pits, dried and stacked, or pumped into tailings ponds on site [16]. They can also be used for several purposes, depending on the original materials. Some samples are reported below:

- Manganese tailings have been used in agro-forestry, buildings and construction materials, coatings, resin, glass, and glazes;
- Clay-rich tailings have been used for making bricks, floor tiles, and cement;
- Red mud from bauxite exploitation has been used as a soil amender, in waste water treatment, and as a raw material for glass, ceramics, and bricks.

Other tailings (from stone industry) investigated in the last decades are residual sludge. Such materials, after a proper characterization and treatment, can be recovered as industrial mineral for brick, mortar, ceramic production [17, 18, 19]. Other studies investigated their employment as soil fertilizer, for the production of artificial soil, as waterproof material for landfills among others [20, 21, 22].

To simplify the concept of “waste recovery” from mine landfills to obtain SRM (and CRM), some samples are reported (Fig. 6-8).

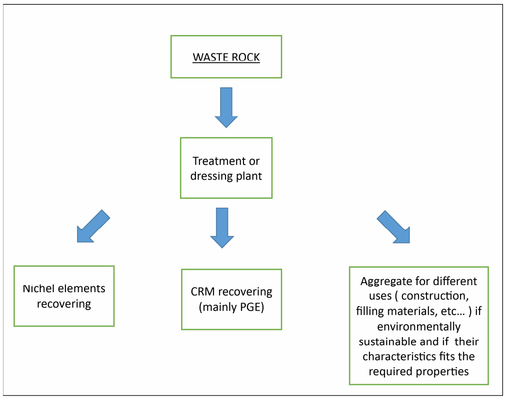

Fig. 6: Secondary raw materials from Ni waste rock

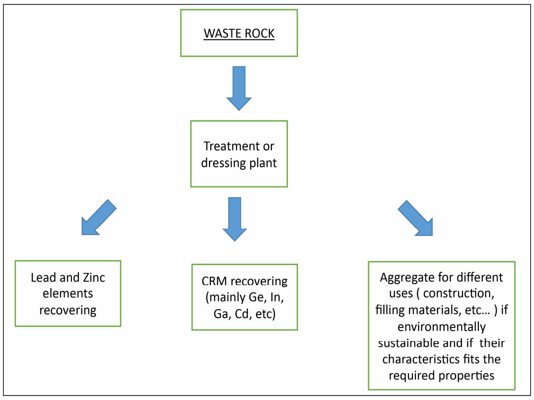

Fig. 7: Secondary raw materials from Zn-Pb waste rock

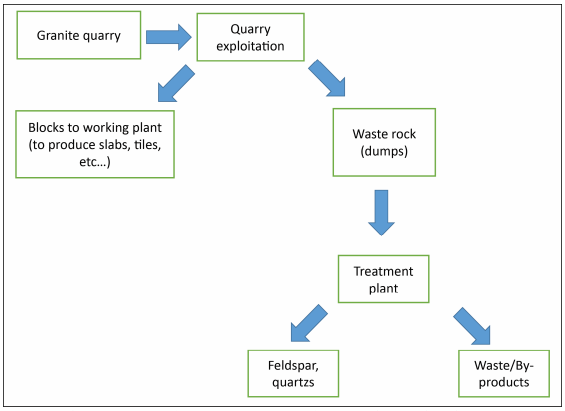

Fig. 8: Secondary raw materials from granite waste rock. Recent researches are investigating the potential presence of rare earth elements.

The specific information about SRM recovery from landfills and waste streams (scientific papers, national and EU projects, etc.) is collected and will be accessible from SG DB. Furthermore, on the basis of these info, 15 pilot sites (seven from extractive industry – closed and operative mine sites) have been selected to test protocols and methodologies useful for SRM assessment (area and materials characterization; environmental, social and economic impacts; cost-benefit analysis, LCA, etc.).

5. Conclusion

This paper presented the Smart ground (SG) project's aims and methods. It contextualized the relevance of the project in terms of resource security and resource recovery that are fundamental for a circular economy. To do so, the project aims to collect and integrate in a single EU databank (SMART GROUND Data Bank) all the data from existing databases and new information retrieved during project activities. Such data is being collected from the different waste streams including municipal, industrial and mining wastes across EU landfills. SG will improve data gathering on secondary raw materials (SRM) from different types of waste, by defining new and integrated data acquisition methods and standards; it will open up understanding and the opportunity for markets in SRM, providing a clear picture of the value of landfill contents and the barriers to recovery. To achieve this, the project provides standard, well tested protocols for landfill data collection/characterization. Furthermore, through life cycle and cost benefit analyses the project will identify the most important sustainability issues for waste streams and SRM. This project will deliver a database that will provide a map of European landfills and extractive industry waste facilities with estimated and actual raw materials available. Furthermore, apart from the knowledge about secondary raw materials it will also provide metaknowledge that is linked to the recovery of secondary materials. For example, the content of a waste product of a mining activity. These project's findings and best practices will be transferred to the different key stakeholders through workshops, conferences and training activities. Only through these knowledge transfer activities will it be possible to maximize impact and implement new approaches within an established market such as the waste sector.

Acknowledgements

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No 641988.

References

[1] "Growth - European Commission." Critical Raw Materials. http://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical/index_en.htm.

[2] European Commission. Reference Document on Best Available Techniques for Management of Tailings and Waste-Rock in Mining Activities; 2009 [cited 2012 August 30]

[3] Hogland W, Hogland M, Marques M. Enhanced landfill mining: material recovery, energy utilization and economics in the EU (Directive) perspective. In: Proceedings International Academic Symposium on Enhanced Landfill Mining. Houthalen-Helchteren 2011; p. 233-247

[4] Vossen W. Aftercare of Landfills and Overview of Traditional and New Technologies. Report prepared for the IIIC project Sufalnet4eu; 2005; Available at: http://www.sufalnet4.eu/ (accessed 30.03.12.).

[5] Bozzola G, Dino GA, Fornaro M, Lorenzi A. Technological innovations and new products obtained from a virtuosos management of mining waste. 4th International Conference on Engineering for Waste and Biomass Valorisation. September 10-13, 2012 – Porto, Portugal; 2012; p. 1879-1884. In Congress Procedia (CDROM). Edited by A. Nzihou and F. Castro. ISBN : 979-10-91526-00-5. Web. Site: http://www.wasteeng.org

[6] http://www.foodwastenetwork.org.uk/

[7] Van Zyl D et al. Mining for the Future. 2002 [cited 2012 August 14]; Available from: http://www.mining.ubc.ca/mlc/presentations_pub/Pub_LVW/68_mftf-mainreport.pdf.

[8] Rajaram R, Melchers RE. Chapter 6: Waste Management, in Sustainable Mining Practices - A Global Perspective, V. Rajaram and S. Dutta, Editors. Leiden, The Netherlands: A. A. Balkema Publishers, a member of Taylor & Francis Group; 2005; p. 193-230.

[9] Dino GA, Marian M. Treatment and exploitation of waste coming from quarry industries: reuse as aggregate. G. Lollino et al. (eds.), Engineering Geology for Society and Territory – Volume 5, DOI: 10.1007/978-3-319-09048-1_17. Switzerland: Springer International Publishing; 2015. p. 89-92

[10] Luodes H, Kauppila PM, Luodes N, Aatos S, Kallioinen J, Luukkanen S, Aalto J. Characteristics and the environmental acceptability of the natural stone quarrying waste rocks. Bull Eng Geol Environ 2012;71:257-261.

[11] Akbulut H, Gürer C. Use of aggregates produced from marble quarry waste in asphalt pavements. Building and Environment. Elsevier; 2007.

[12] Hebhoub H, Aoun H, Belachia M, Houare H, Ghorbel E. Use of waste marble aggregates in concrete. Constr Build Mater 2011;25:167-1171.

[13] Binici H, Shah T, Aksogan O, Kaplan H. Durability of concrete made with granite and marble as recycle aggregates. J Mater Process Tech 2008;208(1):299-308.

[14] Gencel O, Ozel C, Koksal F, Erdogmus E, Martínez-Barrera G, Brostow W. Properties of concrete paving blocks made with waste marble. J Clean Prod 2012;21:62-70.

[15] Montero MA, Jordán MM, Almendro-Candel MB, Sanfeliu MS, Hernández-Crespo MS. The use of a Calcium carbonate residue from the stone industry in manufacturing of ceramic tile bodies. Appl Clay Sci 2009;43:186–189.

[16] Hudson-Edwards KA, Jamieson HE, Lottermoser BG. Mine Waste: Past, Present, Future; 2011 [cited 2012 August 31]; Available from: http://facstaff.uww.edu/bhattacj/mine_waste_overview.pdf.

[17] Careddu N, Marras G. Marble processing for future uses of $CaCO_3$-microfine dust: a study on wearing out of tools and consumable materials in stoneworking factories. Miner Process Extr Metall Rev 2015;36(3):183-191.

[18] Careddu N, Marras G, Siotto, G. Recovery of sawdust resulting from marble processing plants for future uses in high value added products. J Clean Prod 2014;84:533-539.

[19] Díaz LA, Torrecillas R. Porcelain stoneware obtained from the residual muds of serpentinite raw materials. J Eur Ceram Soc 2007;27:2341–2345.

[20] Dino GA, Passarella I, Ajmone-Marsan F. Quarry rehabilitation employing treated residual sludge from dimension stone working plant. Environ Earth Sci 2015;73:7157.

[21] Dino GA, Clemente P, Lasagna M, Passarella I, Ajmone Marsan F, De Luca DA. Industrial chance to recover residual sludge from dimension stones in civil and environmental applications. In: G. Lollino et al., editors. Engineering Geology for Society and Territory – Volume 5. Switzerland: Springer International Publishing; 2015. p. 1309-1313.

[22] Sivrikaya O, Kıyıldı K.R, Karaca Z. Recycling waste from natural stone processing plants to stabilize clayey soil. Environmental Earth Science 2014;71:4397–4407.