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SMART GROUND PROJECT: A NEW APPROACH TO DATA ACCESSIBILITY AND COLLECTION FOR RAW MATERIALS AND SECONDARY RAW MATERIALS IN EUROPE

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Abstract

Steady Raw Materials (RM) supply is essential for the EU economy and increasingly under pressure to sustain the businesses and industries demand. The supply of RM is not only a matter of availability of primary but also of secondary raw materials (SRM). In fact a great amount of waste can be regained as practical and valuable SRM by enhancing the recovery processes from industrial, mining and municipal landfill sites, especially if we consider that Europe is highly dependent on the imports of several RM. Nevertheless, there is to date no inventory of SRM at EU level. Smart Ground project aims to facilitate the availability and accessibility of data and information on SRM in the EU, as well as creating synergy and collaboration between the different stakeholders involved in the SRM value chain. In order to do so, the Smart Ground consortium is carrying out a set of activities to integrate in a single EU database all the data from existing sources and new information retrieving pilot landfills as progress is made. Such database will enable the exchange of contacts and information among the relevant stakeholders, interested in providing or obtaining SRM. Finally, Smart Ground project will also spin out the SRM economy and employment thanks to targeted training activities, organized during congresses and dedicated meeting with stakeholders and end users interested in calculating the potentiality for SRM recovery from selected landfills, contemporary constituting a dedicated network of stakeholders committed to cost-effective research, technology transfer and training.

Key words: circular economy, extractive waste, landfill mining, municipal solid waste, secondary raw materials

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1. Introduction

Raw materials (RM) are essential for the EU economy and sustainable development. Concern about their availability recently led to the definition of critical raw materials (CRM), as materials of high economic importance to the EU combined with a high supply risk (EU Commission, 2017). In 2011, a first list of CRMs was established by the European Commission (EC). In May 2014, the EC published a revised and extended CRM list including 13 of the 14 materials from the previous list, with only tantalum moving out due to a lower supply risk. Six new materials appeared: borates, chromium, coking coal, magnesite, phosphate rock and Si metal, bringing the number up to 20 CRM. The other 14 RM are: Sb, Be, Co, fluorspar, Ga, Ge, In, Mg, natural graphite, Nb, platinum group metals, heavy REE, light REE and W.

Considering the increasing scarcity and raising prices of RM, their recycling and recovery from anthropogenic waste stream deposits is of high relevance. The *European Innovation Partnership* (EIP) on Raw Materials has been established as a stakeholder platform, with the aim to promote innovation on the RMs sector on both technology for waste recovery and development of more efficient recycling processes. CRM and secondary raw materials (SRM) can be recovered from municipal solid waste (MSW), including commercial and industrial waste, as well as from waste from extraction and processing of mineral resources, known as extractive waste (EW). It has been estimated that the number of landfills in Europe is between 150.000 and 350.000 covering more than 300.000 hectares of land (Hogland et al., 2011; Vossen, 2005). Furthermore, the European Enhanced landfill mining consortium reported that the total amount of landfills in Europe is estimated to be >500.000 (EURELCO, 2017). Historical background makes the numerous old waste dumps a possible

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source of CRM and SRM. However, data available on CRM and SRM present in landfills is scarce and there is yet not guidance available on best management practices to recover SRM from landfill sites.

Considering the complexity of the RM value chain, it is fundamental to boost coordination and networking activities; sharing best practices and promoting innovative solutions, with the involvement of stakeholders, citizens and public authorities; thus a more efficient use of RM and waste reduction will be assured.

The opportunity to recover CRM and SRM from urban landfill sites and EW facilities will require substantial investment, which will be initiated and funded by either public or private funding that will boost EU economic growth as well as enhancing the environment and societal quality of life (Dino et al., 2016; Jones et al., 2013; Marella and Raga, 2014). Effective stakeholder involvement is crucial for such opportunity to happen as it is characterized by being dimensionally huge, extremely complex, human-oriented and characterized by considerable impacts to the society, economy and natural environment (Careddu et al., 2013; Suthar et al., 2016).

In this context, Smart Ground project, funded by the EU's Horizon 2020 program (GA 641988), aims to facilitate the availability and accessibility of data and information on SRMs in the EU, as well as creating synergies and collaboration between the different stakeholders involved in the value chain (Dino et al., 2016).

1.1. Smart Ground objectives and activities

The main objectives and actions of the project can be summarized as follows:

a. To obtain quantitative and structural data from both existing and not known SRM resources of the most needed RM and SRM in EU that could be utilized profitably as a RM and/or energy

b. To review existing standards for RM and waste inventory and implement new methodology validated through selected pilot sites, as currently at EU level there is little shared information available for conducting harmonized waste inventory; in particular, there is no EU inventory for EW facilities.

c. To identify the most promising markets for recovered SRMs from the pilot scenarios. As quality and quantity of exploitable SRM/CRM is crucial, characterisation activities and impact analysis must be carried out.

d. To integrate and harmonize data and information collected by gathering them in a single EU database (SG platform), facilitating the access to information on available SRM for end-users. All datasets from the pilot studies and information collected from previous published studies by the partners, as well as from other sources, allowed the Smart Ground consortium to determine the most important characteristics of SRM for waste management decision making at EU level. This platform will be publicly accessible through a web portal that will facilitate the search of SRM-related information. Furthermore, the use of the platform will facilitate the registration and collection of new information from other landfills and EW facilities, thus creating a virtuous cycle "from waste to resource".

e. To raise awareness among policy makers and public opinion to support the social recognisability of the positive impact of landfill exploitation to obtain SRM. Implementing new approaches to decision-making within an established market is extremely challenging. Transferring knowledge into a sector such as the waste sector, which is conservative in approach and where profit margins are not high, requires dedicated resources: Smart Ground project tries to face this challenge.

2. Data Collection plan and validation at pilot sites level

The main waste streams considered in the Smart Ground project are EW and MSW including commercial and industrial waste, and construction and demolition waste (C&DW), which represent 29%, 9% and 32%, respectively of the total EU waste production (Eurostat Statistics, 2012). The knowledge of the quality and quantity of such wastes is fundamental to evaluate the potential SRM exploitable from landfills at large and from the different waste streams. While there is a great deal of information available on MSW and C&DW. To date, there is little detailed data on EW. In order to collect useful information for waste characteristics and volumes of SRM within anthropogenic deposits, a total of 10 sites (4 MSW, industrial landfill sites and 6 EW facilities) have been investigated as pilot sites (see Table 1); other six pilot sites, based on previous published data were also selected for Spain and UK (not included in the present paper).

Table 1. Pilot sites for Data Collection plan validation

Waste stream types	***Name and location***	***Pilot description***	***Status***
Waste from extraction and processing of mineral resources	Montorfano mining area, NW Italy	Feldspar production from granite waste facilities exploitation	Active site
	Gorno mining area, northern Italy	EW facility characterized by a high content in metals as Zn, Pb and possible CRM as Ge, Te, In, Cd etc.	Closed site
	Campello Monti mining area, NW Italy	EW facility characterized by a high content in Ni, Cu, Co and possible CRM as PGE	Closed site
	Aijala mining	EW facilities in Southwest	Closed site

	area, Finland	Finland. Tailings from mining containing Cu, Zn, S, Ag, Au	
	Rudabánya, Hungary	EW facilities containing tailings from sulphides exploitation	Closed site
	Pátka, Hungary	EW facilities containing tailings of fluorite dressing plant	Closed site
Municipal Solid waste (MSW) including commercial & industrial Waste (C&I)	Metsäsairila landfill, Finland	MSW landfill	Both active and closed parts
	Kuusakoski Oy landfill, Finland	Private industry landfill; waste from vehicle and aluminum industry	Active site
	Debrecen, Hungary	MSW landfill	Active site
	CAVIT, La Loggia (Torino, Italy)	C&D waste treatment plant for the production of recycled aggregate	Active site

2.1. Data Collection plan for the characterization of different types of waste deposits

As for MSW landfills the Data Collection plan included the following activities:

1. Collection of preliminary information such as operation history, depth of the landfill cell, degradation stage (for occupational safety), presence of hazardous waste (occupational safety), and geophysical characterization
2. Sampling activity: different sampling techniques were used including drilling, excavating and cactus grab crane for MSW sampling. Sample sorting was done either manually or mechanically to separate the different waste fractions. The physico-chemical characterization of the fractions was then carried (Fig. 1)
3. Sampling preparation to obtain representative samples for analysis (Fig. 1).

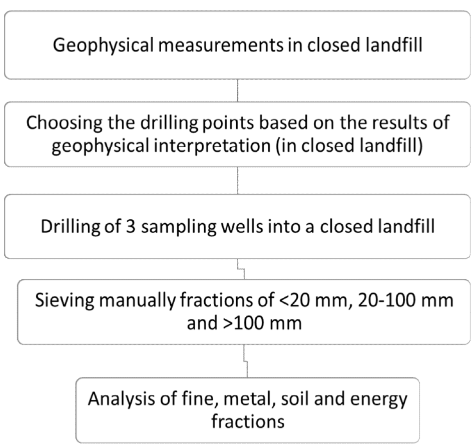


Fig. 1. Flow chart of suggested investigation process in Metsäsairila MSW landfill

As for EW facilities the Data Collection Plan comprises preliminary data collection, field activities and characterization (Fig. 2). In particular:

1. Preliminary data collection about localization, morphology, geology, info about ore bodies, mining and dressing activities, etc.
2. Field activities, which have to be organized into two stages:
   a. Preliminary field activity in order to map the old mine tunnels, access roads, pedestrian paths and waste facilities. This early survey involves the recognition of the main characters of each dump, possibly including some geochemical features with the help of a portable XRF.
   b. Representative sampling of the different types of deposits (waste rock, operating residues and tailings). The sampling of the different types of deposit must be planned on the basis of the info collected during preliminary field activity, together with historical info about mining and dressing activities, info about geology, restrictions present in the area, etc... Representative sampling can generally be performed by applying a net scheme or a random sampling procedure; the samples can be collected using different tools, depending on the characteristics of the area and of the materials, such as: core drilling, excavating, sampling using hand shovel, etc.
3. Characterization, organized in two main stages:
   a. Treatment to obtain representative samples for analysis
   b. Analysis for physical, chemical, mineralogical, petrographic characterization

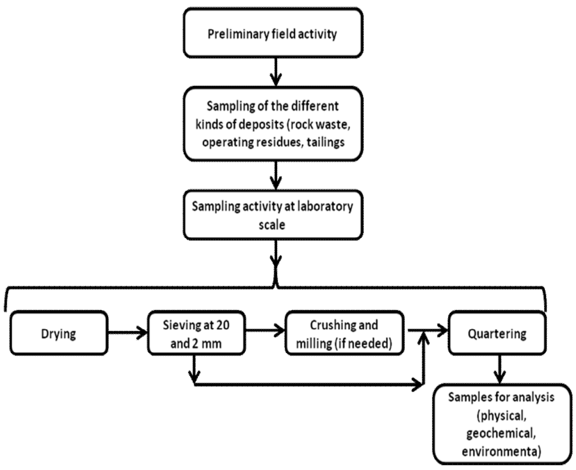


Fig. 2. Flow chart for field activity and characterization phases: EW facilitie

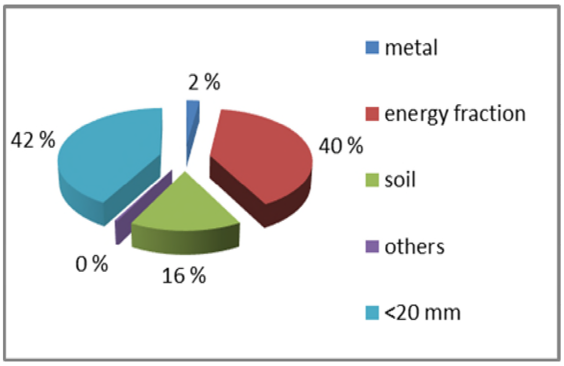
Two pilot sites characterization studies are briefly presented below, as examples: one for MSW and another for EW.

2.2. MSW pilot site characterization: Metsäsairila landfill

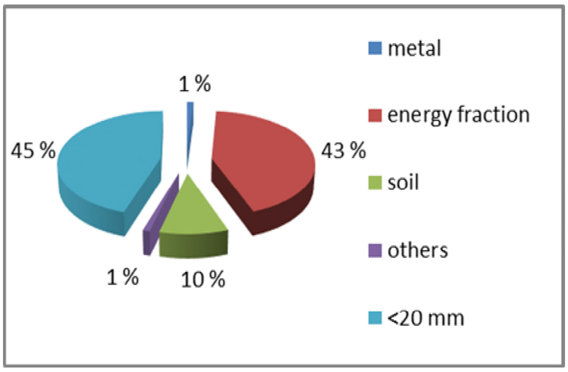
Metsäsairila landfill is located in the City of Mikkeli around 200 km from Helsinki, in South-Eastern part of Finland. It has been operating since the beginning of 1970s, but the old part of the landfill was closed in 2007 and the new part opened in the same year. The surface area of the old landfill is around 8 ha and the currently active area around 3 ha. Waste in old and new areas consists mainly of MSW but also some industrial, C&DW and hospital waste have been deposited in the landfill area.

Sample collection wells were drilled by hydraulic piling rig from 5m until 17m depth, depending on sampling well, after removal of top layers of the landfill including cover materials. Aggregate waste samples from each well were taken to a sorting point, where they were manually sorted to different particle size categories (>100 mm, 20–100 mm and <20mm) and waste fractions by sieves. Waste fraction separation was carried out to fraction sizes of 20-100 mm and >100 mm and transferred to separate big plastic bags. Material size of <20 mm was packed in buckets. After the weighing procedure, all aggregate samples were transferred to laboratory for detailed analysis. Analysis of samples for elements, total organic carbon (TOC), dissolved organic carbon (DOC), chloride, and fluoride was implemented in an external laboratory (ALS Finland Oy). X-ray fluorescence (XRF) analysis for metals and calorimetric values for energy fraction were measured at Mikkeli University of Applied Sciences (Mamk).

Percentage distribution of different waste fractions is shown in Fig. 3.a and 3.b. Waste fraction distribution is quite similar in closed and currently active area; however, active area has more energy and fine material (<20 mm) fractions. Detailed results on the characterization of Metsäsairila MSW landfill are presented in annual research publication by Mamk (Soininen et al., 2016).



a



b

Fig. 3. a. Percentage distribution of sorted waste fractions from sampling well drilled in closed landfill area; **b.** in currently active landfill area

2.3. EW pilot site characterization: Campello Monti mining area

Campello Monti is located in Strona Valley (NW Italian Alps), at 1305m a.s.l. in the Verbano Cusio Ossola District (Piedmont Region). From the geological point of view the area is within the Ivrea Verbano Zone, a lower crust continental unit made of a voluminous body of mafic magmatic rocks intruded in a metasedimentary sequence. The mafic formation consists of cumulate peridotite, pyroxenite, gabbro and anorthosite grading to gabbro-norite, gabbro-diorite and diorite.

The mineralization occurs mainly within the pyroxenites and the ore assemblage is given by pyrrhotite, pentlandite and chalcopyrite, with locally PGE (platinum-group elements) enrichments (Rossetti et al., 2017).

The first historical information about the nickel mines of Campello Monti dates back to 1865 and the mining activity continued until the 2nd World War. The orebodies occurred as subvertical lenses broadly striking N-S to NNE-SSW, with an average grade of ca. 1-2 Ni wt. % (0.5 wt. % in the last years of activity). Nickel was extracted from pentlandite, as both relatively coarse-grained intergrowths and very fine-grained exsolutions in pyrrhotite.

Extractive waste facilities in Campello Monti are represented by:

• Waste rock: the most important waste materials in the area. The waste occurs in dumps, mainly located on the left side of the valley (WNW of the Campello Monti village).

• Operating residues: materials related to a first phase of dressing activity, cropping out in two sites: a first one on the lower-left side of the valley, close to the dressing plant, and a second one 200 m far away, on the opposite side of the valley. While the first one is a concentration of the material after milling, the second one is material deposited before transportation to the dressing plant.

Field activities have been organized into two stages: the preliminary field activity and the sampling of the different types of deposits (waste rock and operating residues). Each sample has been collected in an area of 1.5 square meters, which had been cleaned from the organic residues. After cleaning, the samples have been collected using hand shove, and, where necessary, hammer to reduce the grain size of the rock (Rossetti et al., 2017).

A total of 41 samples of rock waste and 12 of operating residues were collected.

All the samples have been taken to the Mineral Dressing and Sampling Laboratory (University of Torino) to be treated (dried, sieved at 20 and 2 mm, quartered and, when needed, crushed and milled) in order to obtain samples to be analyzed (physical, geochemical and environmental analysis).

The samples for geochemical analysis (important for SRM evaluation) were sent to an external laboratory (ACTLABS, Canada) and investigated for multi-elements geochemistry by ICP-MS and ICP-OES methods. Preliminary analyses have been performed on samples of three size classes (>20 mm, 20-2 mm, <2 mm) in order to verify the existence of significant compositional differences. As differences were not significant, the subsequent analyses were performed on the whole sample. Based on the preliminary results, part of the samples was selected for PGE analyses.

The geochemical data point out important differences among the waste deposits, in agreement with the field observations. In particular, four composition groups are recognized (Fig. 4): 1) operating residues extremely enriched in Ni (> 10.000 ppm), Cu (≥ 5 .000 ppm) and Co (> 600 ppm); 2) operating residues and waste rocks strongly enriched in the same metals; 3) waste rocks only moderately enriched in Ni, Cu and Co; 4) waste rocks characterized by a metals content relatively low, quite similar to ultramafic rocks not mineralized. The mineralogical and petrographic study, performed under optical and electron microscopy, shows that Ni, Cu and Co occur within minerals (metal sulphides) suitable for metals recovery.

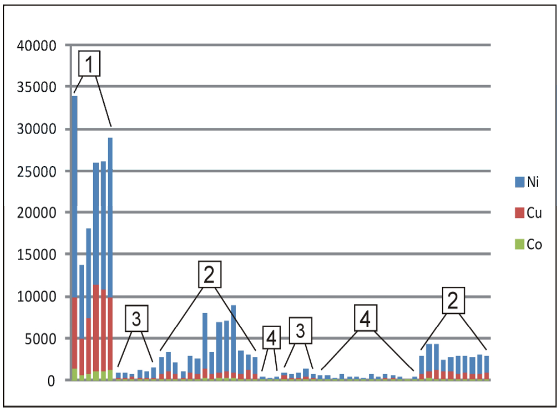


Fig. 4. Ni, Cu and Co content of samples from the Campello Monti area (values in ppm). The numbers refer to the four composition groups described in text

Preliminary data show that the PGE content is highly variable, the highest enrichments occurring in samples of the first composition group described above; PGE are mainly represented by Pd and Pt (Pd+Pd: up to ~0.8 ppm).

3. Materials flow, socio-economic and environmental impacts

Although landfill mining (LFM) could be a good solution for recovering SRM, LFM operations could have significant social, economic and environmental impacts (Garamvölgyi, 2016). These factors have been taken into account during the project activities, and qualtitative and or quantititaive information when available has been implemented the SG platform to assist user under the potential pros and cons of landfill mining. Environmental, social and economic impacts have been evaluated for different scenarios for the selected pilot sites in order to test the proposed methodologies.

3.1. Reasons for and against landfill mining

Reasons for LFM operations are either based on economic or environmental reasons. According to studies (Fisher, 2013; Warren and Read, 2014), main reasons for extraction can be:

- recycling potential – focusing on materials with the highest value and lowest degradation rate like metals,
- extraction for energy recovery – focusing on un-degraded biomass as a short term solution (mainly connected to MSW), or
- land reclamation, where the landfill site is a physical barrier to a development.

Besides the main reasons mentioned above, studies show that LFM could result in extension of the lifespan of landfill, by recovering the void space for reuse for different kinds of waste more suitable for long-term disposal. Also, if landfill is contaminating the groundwater and surrounding area, the source could be removed and further contamination could be prevented.

Despite benefits, LFM operations could have significant reasons against. Environmental risks of excavation of a landfill site include: nuisance caused during the LFM operation, potential presence of hazardous materials (such as asbestos), and escape of leachate or landfill gas (LFG) during the LFM operations and residual contamination of land or groundwater, which should be removed. Many of these risks are related to traditional mining operations, but are increased by the heterogeneous nature of waste in landfill (Fisher, 2013).

Uncertainty of LFM output is a clear economic risk for investors. There is a big concern whether the excavated materials will be marketable or not. Primary RM are qualitatively superior compared to recovered landfilled ones which are likely contaminated and not totally recyclable (Fisher, 2013; Warren and Read, 2014).

3.2. Identifying environmental impacts

There are numerous negative effects which landfill mining may cause. In general, it may lead to release of dust, liquids and leachate, landfill gases (LFG) and odours (expecially for MSW), with a risk to human health.

Hazardous waste is often uncovered, especially in older landfills where waste disposal practices and acceptance criteria were not very strict. Excavation of a landfill area could undermine the integrity of adjoining cells, which could lead to subsidence or collapse of landfill but also may attract various vermins. Landfill mining would certainly create noise and lead to additional traffic flow on the local road network (Ford et al., 2013).

Life Cycle Assessment (LCA) is suitable for identifying environmental impacts of different LFM or EW exploitation scenarios. Documented research investigated the difference in impacts between leaving the landfill to naturally degrade against the impact of a possible LFM project; the use of recovered materials as substitute; and RDF extracted from landfill compared to the use of traditional fossil fuels (Fisher, 2013).

3.3. Economic impacts - Investment decision making

According to a study from Scotland (Warren and Read, 2014) LFM is rarely self-sufficient. Economically viable cases usually include LFM operations involving onsite energy recovery at non-hazardous landfills; excavation, shredding, screening and removal of ferrous metal, with sale of metals; recovery of soil for use as daily cover. Besides, compaction of waste may be economically viable based on the recovery of void space.

LFM with resource and off-site energy recovery might be feasible where wastes are excavated anyway, assuming that the alternative is to pay for landfill elsewhere. In cases where industrial wastes are also landfilled more valuable materials can be recovered, thus resulting in economically feasible solutions (Ford et al., 2013). Some examples of profitable RM and SRM recovery from EW facilities still exits, mainly as for waste coming from recovery of dimension stone waste (Bozzola et al., 2010).

Consequently, waste composition, historic operating conditions, extent of waste degradation and market prices for recovered materials have also to be considered for LFM feasibility decisions.

3.4. Social impacts

LFM operations have significant social impact on local residents. LFM could lead to road congestion based on the intensive process activities near the landfill. At the same time there could be considerable concern over health, comfort and nuisance impact due to LFM process. Besides, decrease in value of properties which are close to landfill during the period of LFM can also occur (Ford et al., 2013).

However, after the removal of landfilled wastes, the value of those properties can increase. Excavation of landfill, as a process that reduces or eliminates on-going risks and impacts on health and the environment, would also imply new workplaces not just for experts but for low-skilled workers as well. Therefore, communication towards the local residents is always crucial in LFM strategies (Ford et al., 2013; Garamvölgyi, 2016).

3.5. Smart Ground approach for Data collection

LFM calls for an appropriate technology to result in marketable SRM to fully achieve economic and environmental goals. To model such approaches, scenario models are being assembled in the framework of the Smart Ground project. These scenario models cover not only pilot landfills, but a feasible technology line modelled by inputs, outputs and impacts (Fig. 5) to produce SRM from the excavated input originated from the landfill site. Besides, marketability will also be investigated in the scenario model in detail to identify industrial needs for the corresponding SRM.

First results available indicated that despite the highest environmental impact due to the recovery processes, savings gained from SRM as substitute material are often higher. Savings highly depend on recovered SRM types.

As impacts of processes involved are often dominated by their energy need, overall environmental savings of the LFM or EW exploitation processes are highly determined by local energy mixes.

Nevertheless economic burdens can hinder LFM and EW exploitation activities under the current economic circumstances.

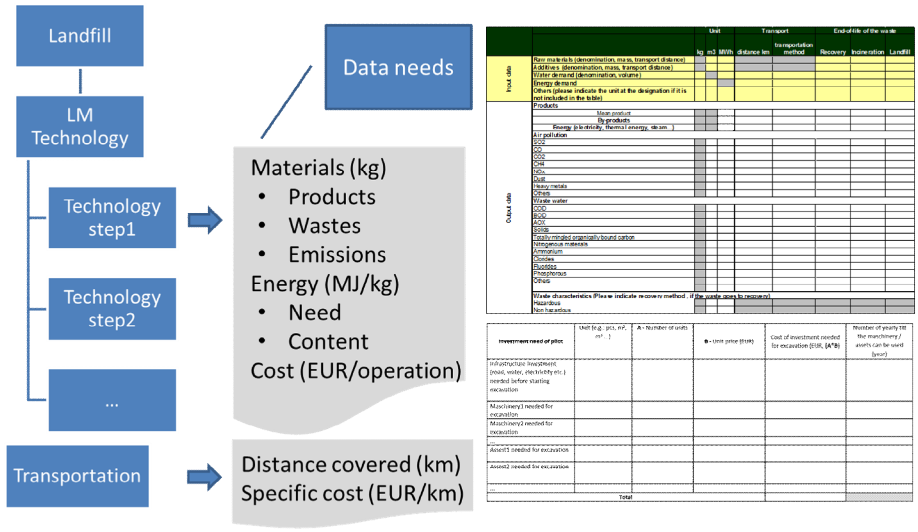


Fig. 5. Data collection for scenario models in the Smart Ground framework

4. Smart Ground Databank platform

The Smart Ground IT infrastructure relies on an open source, modular architecture, which provides a reliable, scalable and responsive application, and enables spatial visualisation, search and analysis of the waste sites. The following diagram shows the platform's high level components (Fig. 6).

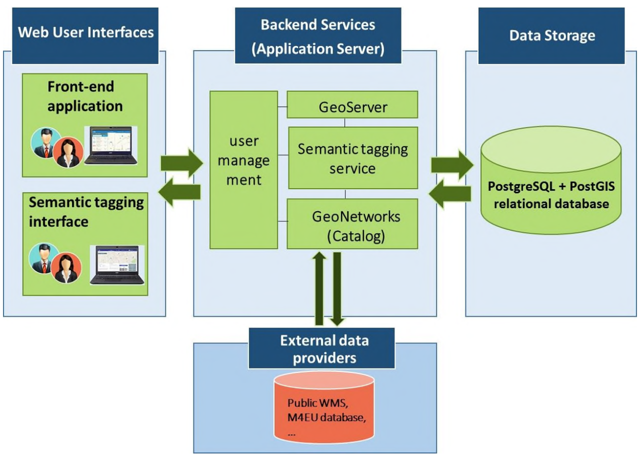


Fig. 6. High level components of Smart Ground Platform

4.1. Data Storage

The Smart Ground internal database will store heterogeneous information regarding the characterisation of waste sites, availability of RM, technologies involved, thematic maps, and the ontology or meta knowledge which formalises the personal knowledge provided by each user.

The technology chosen for the database is PostgreSQL (PostgreSQL, 2017) with PostGIS (PostGIS, 2017) extension, which is a leader in open source geospatial databases. PostGIS is fast, has a lot of GIS features and can be used from GeoServer.

A data model is currently being developed based on an iterative approach, supporting the storage of the above mentioned information and allowing the queries of the target users.

For the development of the Smart Ground data model several activities and projects were evaluated, primarily the INSPIRE Data Specification on Mineral Resources (INSPIRE, 2013) and the project Minerals4EU (Minerals4EU, 2017). Best practices such as table structure, naming conventions and the greater possible number of tables and code lists (dictionaries with predefined values) were reused to facilitate interoperability and mapping between data of the related platforms.

4.2. Backend Services

This category includes the components that serve the front-end services, having the capability to communicate with the required resources (internal database or third party services).

• **GeoServer** has been chosen as geospatial data server which is used for vector data rendering, publishing OGC services (WMS, WFS), serving plenty of different raster and vector data formats, or creating our own base map.

• **Semantic Tagging Service:** this service semantically enriches the data collected and aggregated in Smart Ground databank repositories, creating a layer of semantic annotations on top of them, and publishes these annotations as open linked data. The resulting ontology is expressed by means of the Resource Description Framework (RDF) formalism, which provides the tools to organize the information in form of a semantic graph where each node represents a concept, and each edge represents a predicate, i.e. a property, holding between two concepts. In particular, an RDF statement is an expression that asserts that a given relationship (called a predicate) holds between two concepts, a subject and an object, and represents the building block of the ontology. The ultimate purpose is to expand the scope of the classic database interrogation tools, namely SQL queries, thus combining the factual data with the meta-knowledge represented in the ontology, allowing each user the possibility to filter/extend the information extracted from the database according to their personal knowledge.

• **GeoNetwork:** Smart Ground information will be described and published in the catalog so that third parties can explore our database. It will also facilitate Smart Ground users to search data across multiple catalogs, e.g. ProSUM or MINERALS4EU.

- **User Management Service**: This component enables the security features such as authentication, authorization and user management across the services and components of Smart Ground.

4.3. Web User Interfaces

Two user interfaces are planned, one supports the decision making of different stakeholders regarding SRM available in waste sites, while the other aims at developing a RM thematic ontology (meta-knowledge).

- **Front-End Application:** this is the website that the end-user sees and acts on to display and collect all the information for the main functionality of the platform. It will be composed of a map viewer, a layer manager and a window to display most of the dynamic information. Planned functionalities include: management of operators' waste sites, and search and exploration of waste sites and RM of interest, calculation of predictions for specific waste sites.

The user interface is optimised for a desktop browser, appropriate for use inside a customer's organisation, as it will be the case for Smart Ground.

- **Semantic tagging interface:** It offers the Smart Ground users a way to make available their own knowledge, while also providing the tools to extend the traditional database query process to take into account both the existing factual data, as stored in the database, and the personal knowledge laid down by each user.

There are four ways for the users to enrich the system with their personal knowledge:

  - By adding a statement to the ontology: the user can select a subject and an object from the existing concepts and connect the two by means of a predefined property.
  - By defining a new concept, which can be interpreted as a subject or an object in a new set of statements.
  - By defining a new property, providing a new way to connect existing concepts in the ontology.
  - By including other users' personal knowledge, whether concepts, properties or entire statements.

Technical details about the semantic tagging interface are described in Di Mauro et al. (2016).

5. Implementing new approaches to decision-making within an established market, transferring knowledge

CRM and SRM recovery projects involve a wide range of stakeholders who come from diverse backgrounds and raise various issues that are at stake in the project (Lapko et al., 2016). These concerns might be favourably or unfavourably affected owing to the achievement of project objectives (Careddu et al., 2013; Frändegård et al., 2015). Although they are often conflicting and relate to diverse topics, stakeholder concerns springing from a CRM and SRM recovery projects are bonded with strong and dynamic interdependencies. As such, to maximize impact and implement new approaches in this sector, the Smart Ground project is developing a comprehensive stakeholder's analysis and training plan.

5.1. Stakeholder analysis methodology and results

The stakeholder analysis is designed as a four-step process and includes the following steps: (i) identifying stakeholders across European countries (ii) categorizing and mapping stakeholders (iii) identifying stakeholder allegiance and (iv) investigating stakeholders' knowledge, interests, positions, alliances, and importance related to the policy. To ensure low carbon footprint and minimize burden on stakeholders, a three stage online questionnaire using Qualtrics® software was used. The stage 1 survey, covering questions regarding the 'State of landfill mining and CRM recovery in the EU' was circulated to first interviewees' list of stakeholders (40 people) created following suggestions given by the Smart Ground experts in the field of MSW and EW management. In the stage 2 the survey was refined following feedbacks received and then sent to 750 stakeholders across 14 EU countries. Due to the low response rate, a stage 3 survey was sent to the updated database of 900 stakeholders. For this stage, the survey followed the same structure as the stage 2 survey but some aspects of the survey were shortened and simplified with the aim of reducing the number of stakeholders leaving the survey. Stakeholders have been classified into five categories according to their social roles, named administration, state-owned enterprise, private enterprise, research institute, social organizations and other types. The survey was available in 8 languages including English, Finnish, French, Hungarian, Italian, German, Portuguese and Spanish. The survey is available at Secondary Raw Materials recovery opportunities in EU.

From the 900 participants invited to complete the survey, 191 stakeholders opened it (21%). Completion rate of the survey was 53% (101 responses recorded in full for the survey) and 47% (90 partial responses recorded or participants left the survey within a minute). Survey respondents needed an average time of 20 minutes to answer the survey).

63% of survey respondents were classified as "Key Players". Stakeholders within this category are the key stakeholders with high influence/power and high interest and therefore, the group The Smart Ground consortium should dedicate more efforts and tailor training activities and project outputs. Besides, identifying their profile, sector, needs, perceived opportunities and perceived barriers has served as a basis for developing the stakeholder engagement strategies, training, networking and implementation strategies.

The sectors most represented by "Key Players" are the Recycling and waste management sector (27%), the Extractive industries (mines) (12%), Renewable energy (8%), Construction (7%) and Energy (7%). 21% stated "Other" as their industry sector (Fig. 7).

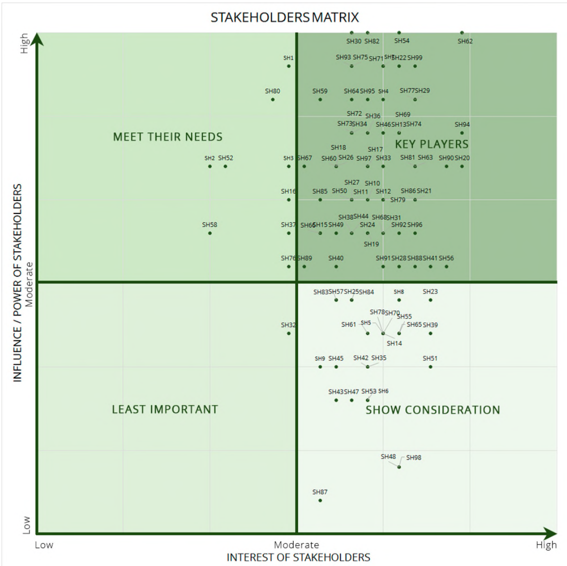


Fig. 7. Power vs interest grid for Smart Ground stakeholders

Further to the power *vs* interest grid, a stakeholders' influence analysis was carried out. Regulators and Governmental agencies are the most influential stakeholders, followed by Site owners, Site operators and Academics/researchers (Fig. 8). Therefore, the consortium should target networking and training activities towards these stakeholders as this will have a cascading effect down the network to all stakeholders. Therefore, Smart Ground materials will look to incorporate, where possible, the views and needs of all these groups.

This stakeholder analysis has provided the Smart Ground project with complex and in-depth information regarding the different stakeholders involved, their importance and interactions and their views and concerns regarding LFM.

Fig. 9 summarises the opportunities and factors promoting LFM and the barriers, limitations and bottleneck as perceived by the stakeholders. Important to note is that economic factors were most important across all stakeholder groups for both positive and negative stances. Therefore, Smart Ground will aim to focus on economic factors in their output material and to facilitate discussion and knowledge-sharing in order to engage stakeholders in these topics to facilitate solutions and promote opportunities.

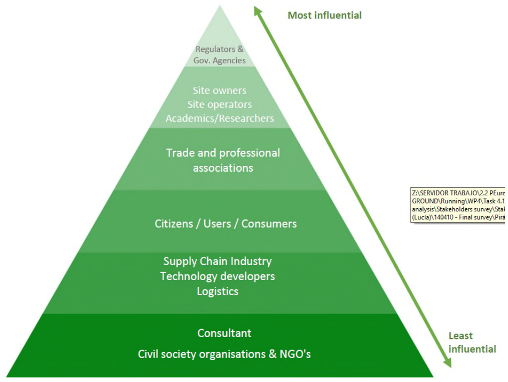


Fig. 8. Influence pyramid

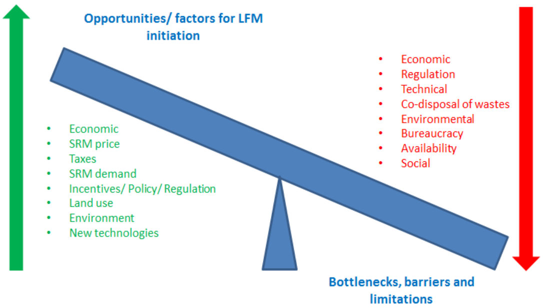


Fig. 9. Opportunities and barriers identified by the stakeholder analysis

Stakeholders also indicated a general willingness to share experiences, provide technical support and advice as well as case studies on best practices and successful LFM projects.

5.2. Smart Ground training materials

The training materials developed consist of (1) a landfill mining toolkit, (2) a range of decision support tools (DST) enabled through the Smart Ground database and (3) an E-book.

The landfill mining toolkit has been designed to give stakeholders information about what is needed to initiate CRM/SRM recovery from landfill sites or EW facilities, and scope out the potential viability of reuse of CRM/SRM in their specific circumstances. The toolkit cannot however been used to provide a full engineering study of your project or a complete and detailed business case. Rather it will give the users the understanding and basic data to allow users to progress into more detailed analysis with potential suppliers and technical advisors to build a technical and business case for your project.

The second material developed is the Smart Ground database and associated decision support tools. The database provides guidance on the validity of a potential landfill mining project. It will serve as an indication that should be followed by specific site analysis. The associated DST will be based on the waste age in a landfill, site life and other economic factors such as revenue of the additional space, value of the recovered soil and the avoided costs. Finally, the last material is the E- Book. The E- Book is an interactive pdf that will be available on Smart Ground website. It will be a stand-alone knowledge transfer output including online tools, decision support tool and toolkit.

6. Results and discussion

One of the results of the project is a shared a Data Collection Plan for the characterization of different types of waste deposits. Such Data Collection Plan includes field sampling, samples preparation and analyses protocols. The methodologies and protocols for field survey, sampling and characterization phases have been developed and validated through in-depth characterization studies of ten selected pilot landfills with strongly different characters: two samples are reported in the present paper. The validation phase suggest that such a methodology can be adopted for the estimation of the SRMs potential in landfill and facilities.

Furthermore, the data gathering about the specific waste streams, the technologies to recover SRMs/CRMs and the potential impacts (environmental, economic, social) associated to different scenarios, is fundamental to evaluate CBA and LCA on specific case studies. Modelling and decision support tools are in progress. They will predict the distribution of SRM available across EU landfills to allow targeted SRM recovery market.

The main achievement of the SG platform is the design of a data model to store the relevant information of waste sites which allows to register, search and access relevant information (materials, processing activities, samples, etc.) for the waste materials community (waste operators, public administrations, voluntary activists) at European scale. This complex data can be screened out by the platform using a range of search filters that will suit needs of different stakeholders. When ready (at the end of the project, March 2018), the SG platform will allow end-users to identify and match the supply and demand for SRM by interrogating the data and identifying suitable urban waste landfill sites and/or EW facilities for SRM recovery and other valuable materials. The platform is intended to provide a reliable and transparent source of harmonised and validated information on SRM estimates from anthropogenic deposits available across Europe.

The collection of the information is key for the adoption of the platform. It is not possible to implement a data harvesting system that automatically collects information from other public national platforms given the heterogeneous models, concepts, and languages of each database. In order to integrate information from external database the consortium has to deal on a case by case basis. Instead, the collection of data relies mainly in the engagement of different actors that will upload the information into the platform. When the platform moves in the future to operational phase the authenticity of data will have to be reviewed.

The development of added-value information and services on top of the baseline information will be important to support the adoption of the platform and establish a viable business model. In this regard the project is developing estimation of amounts based on the samples registered for each site. In the future the integration of real-time information from external sources will be considered e.g. market prices, environmental or social indicators.

The integration of the main platform with the semantic tagging module in the form of semantic queries is not without challenges. The users will define personal ontologies with new relationships for which the ecstatic search engine of the platform is not designed. In particular, users will be able to express factual knowledge not planned for at the data schema definition time (such as properties or attributes which might become relevant in the future, within the context of new laws and norms to be enforced), as well as personal, either persistent or temporary knowledge that they would like to use in the context of their access to the platform, to simulate some form of hypothetical queries (What-if queries, with the condition expressed in the form of temporary, personal knowledge). Finally, the development of proper guidelines and best practices to recover waste from landfill and to recycle it into new products is useful to boost the systematic recovery of SRMs and CRMs from landfills and facilities. A continuous cooperation with past and ongoing EU projects and networks (ProSUM, SCREEN, Minerals4EU, EURELCO) has been assured, together with a close cooperation with EC initiatives as the Raw Materials Information System (RMIS).

Smart Ground findings and best practices will be transferred to different stakeholders to maximize its impact and to establish new approaches in the waste sector.

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