# Good practice guide for strategic orientation study and for remediation project related to landfill


Re-use
Scan
Recover
RAWFILL
Describe
Prioritise

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## I. Background

### 1. Purpose of this guide

The purpose of this good practice guide is to provide key elements to conduct a strategic orientation study efficiently prior to setting up a landfill remediation project. In this guide, the different types of landfill remediation project[1] are presented and discussed. Landfill mining is one of the solutions for a sustainable resource management. Landfills are nowadays considered to be a long-term and dynamic stock of resources inside the so-called circular economy. In this context, Landfill Mining is an efficient solution to the transition from traditional waste management to sustainable resource management.

This guide is intended for a broader audience from landfill owners and project managers to local and regional competent authorities eager to be involved in landfill remediation project. Several aspects of dynamic landfill management and landfill site characterization are presented. In the first part of this guide, a quick overview of the RAWFILL project and the European framework for enhanced landfill mining (ELFM) project and landfill rehabilitation are provided. The second part of the guide is about the landfill sustainable and dynamic management. This part is dedicated to the explanation of the RAWFILL methodology which aims at fully characterizing a landfill, and to the conceptualization of landfill remediation project. In the third part, useful documentation to go further in the landfill sustainable management are listed.

### 2. Introduction to the RAWFILL project

This good practice guide has been developed within the framework of the RAWFILL project. RAWFILL (acronym for "Supporting a new circular economy for RAW materials recovered from landFILLs") is an EU-funded landfill mining project aiming at facilitating the implementation of landfill mining project in North- West Europe (NWE) region. RAWFILL offers an evidence-based methodology (including innovative landfill characterization content methodology combining geophysical imaging and targeted waste sampling). The project promotes the standardization of enhanced landfill inventories in North-West Europe, in order to support, through its multicriteria decision support tools Cedalion and Orion, new business models taking into account the resource recovery potential of landfills (material, land and energy) and temporary land use of the landfill site (i.e. interim use). More information about the project and the tools developed can be found on the RAWFILL website and in the Landfill miner guide.

### 3. European Framework

Starting an Enhanced landfill mining (ELFM) project is a long journey which requires to tackle several legislative and technical barriers. One main barrier is related to the fact that in most of the NWE regions, there is no specific legislation regulating landfill mining activities. However, regional authorities have customized their own legislative framework based on environmental permitting, landfill rehabilitation and soil remediation legislation to compensate for the lack of consensus at EU Level[2]. Sometimes, this legislation is in conflict with each other and can lead to

[1] Remediation of a landfill includes landfill rehabilitation, landfill mining, landfill rehabilitation and mixed solutions.

[2] The European directive 1999/31/EC on landfills does not provide specific operational standards for the mining of landfills, and therefore it does not prohibit their operation. The European Parliament resolution of July 9, 2015 on "Resource efficiency: moving towards a circular economy (2014/2208(INI))" clearly indicates the necessity of innovation and policy transition when it comes to resource management. Parliament fully supports the transition towards a circular economy and point attention to 80 measures to the European commission in view of this policy change. Measure 40 calls on the EC to further investigate the feasibility of

important difficulties in the implementation of the landfill mining operations. **Figure 1** shows a flowchart applicable to the landfill management based on the existing regional regulations. The flowchart aims at deciphering which legislation and permitting should be used depending on the type of intervention required on a landfill. As landfill mining is a rather new and innovative concept and due the lack of dedicated regulations, it is also important to organize round table with the competent regional authorities to discuss how the current legislation can be adapted regarding a specific landfill remediation project and to analyze the best way to design studies and permitting operations.

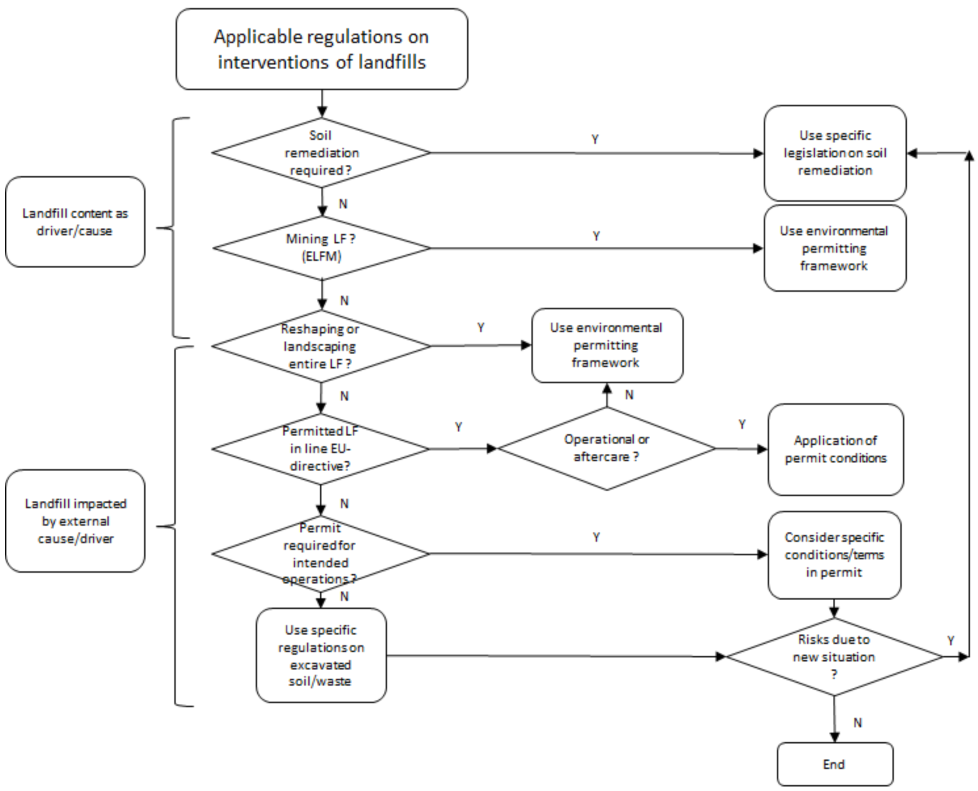



*Figure 1 - Flowchart on applicable regulations in view of interventions on landfills (Wille, pers. com.).*

In most cases, to obtain the authorization/permit to start a landfill remediation project, studies, sampling and analyses are generally required by the competent regional authorities. In the following, a brief overview is provided. However, this section may not be exhaustive and the list of required studies may vary for the different NWE regions.

- ***Soil study***: To assess the impact of the landfill on its environment, a soil study is generally required. The aim of this study is to define the vertical and horizontal extent of the waste deposits as well as the soil pollution (including possible groundwater contamination) associated with them. All the technical modalities are

proposing a regulatory framework for ELFM to permit the retrieval of secondary raw materials that are present in existing landfills. However, at the time of writing this guide (2021), no EU framework for ELFM have been set up.

defined by the regional authorities. The RAWFILL project offers assistance on the data collection (ELIF and geophysical prospecting) and the decision-making process.

- **Site-specific risk assessment study**: In general, landfills are considered as potentially contaminated sites. Once the contamination has been established, it is necessary to delimit the contamination and determine whether it poses a risk to the environment and/or the human health.

- **Environmental impact assessment study:** to evaluate the impact of the landfill on its environment (soil, air, groundwater and surface water) as well as to assess the impact of large landfill remediation project on the environment (e.g. waste transport, human health) and how to mitigate the impacts.

- **Biodiversity survey:** The biodiversity survey aims at assessing the fauna and flora species present on the landfill site. This biodiversity survey is required to follow the European and Regional legislation regarding the nature monitoring and reporting. It should contain several items:
  - A general assessment of the biodiversity on site;
  - Exhaustive list of species present on site;
  - Exhaustive list of invasive species present on site;
  - Site specification measurements to adopt to protect the specific flora and fauna during the landfill mining operations;
  - Definition of the project working periods to protect animals on site;
  - Assessment of the landfill rehabilitation project on the fauna and flora;
  - Site specification measurements to adopt to protect the specific flora and fauna on site and to redevelop biodiversity following the landfill mining operations.

- **Landfill rehabilitation study:** General technical requirements for landfill capping and aftercare operations are based on EU Directive 1999/31/CE[3].

## II. LANDFILL SUSTAINABLE AND DYNAMIC MANAGEMENT

### 2. Application of the RAWFILL Methodology

The RAWFILL methodology was developed to help landfill owners and project managers to fully characterize a landfill from A to Z and identify most relevant LFM projects. It provides an accurate overview of a landfill, which is the key to develop a sustainable management project on it. The steps of the RAWFILL methodology are summarized in **Figure 2**.

[3] Annex 1 - §3.3 and Annex 3.

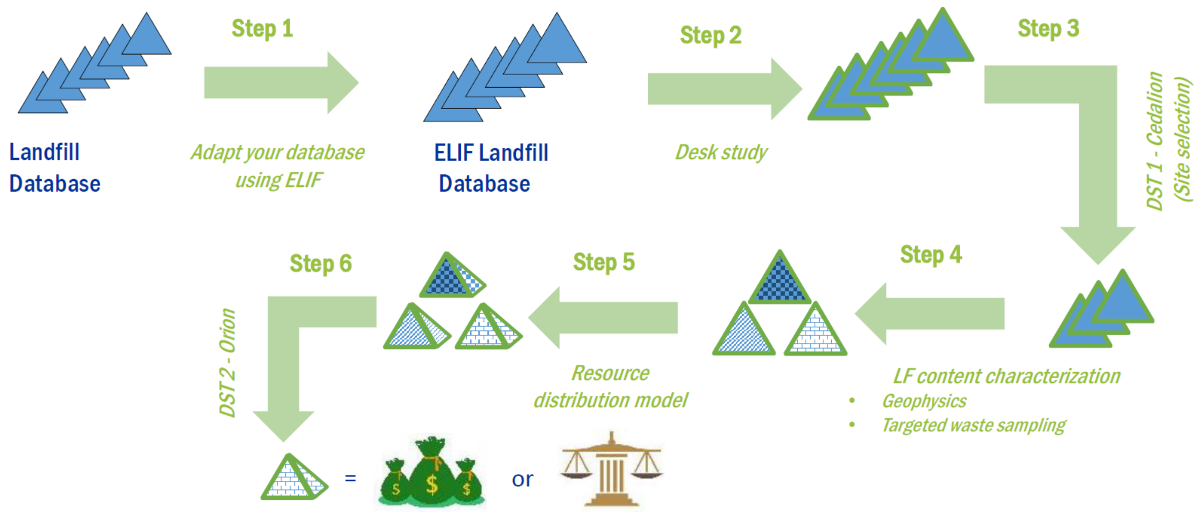



*Figure 2 – The RAWFILL methodology.*

Collecting data to increase the knowledge of a landfill is one of the main steps of the process. Therefore, all the relevant data collected are centralized in the Enhanced landfill Inventory Framework (ELIF) developed by the RAWFILL project partners. ELIF is a landfill inventory structure focused on data regarding resources (content) that can be extracted from a landfill (materials, energy carriers and land) and potential interim uses. It also combines all aspects related to landfills (context): administrative, environmental, social, technical and economical. The added value of this landfill inventory structure is that it includes parameters regarding the economic potential and the social impact of landfill sites. ELIF (excel spreadsheet format) can be downloaded on the RAWFILL website.

**Desk study – Inventory report**

An inventory report of all data already available for a landfill site is the first step to complete the ELIF. To fill it, the following levels of information should be analysed, from the more general to the more specific:

- National/Regional generic databases of contaminated sites including landfills (e.g. BASIAS-BASOL in France, Walsols in Wallonia, DOV in Flanders[4]);
- Historical documents related to the activities on site (e.g. permits, duration of exploitation, list of accepted waste, pictures, aerial photography and maps, testimonies);
- Site visit.

**ELIF**

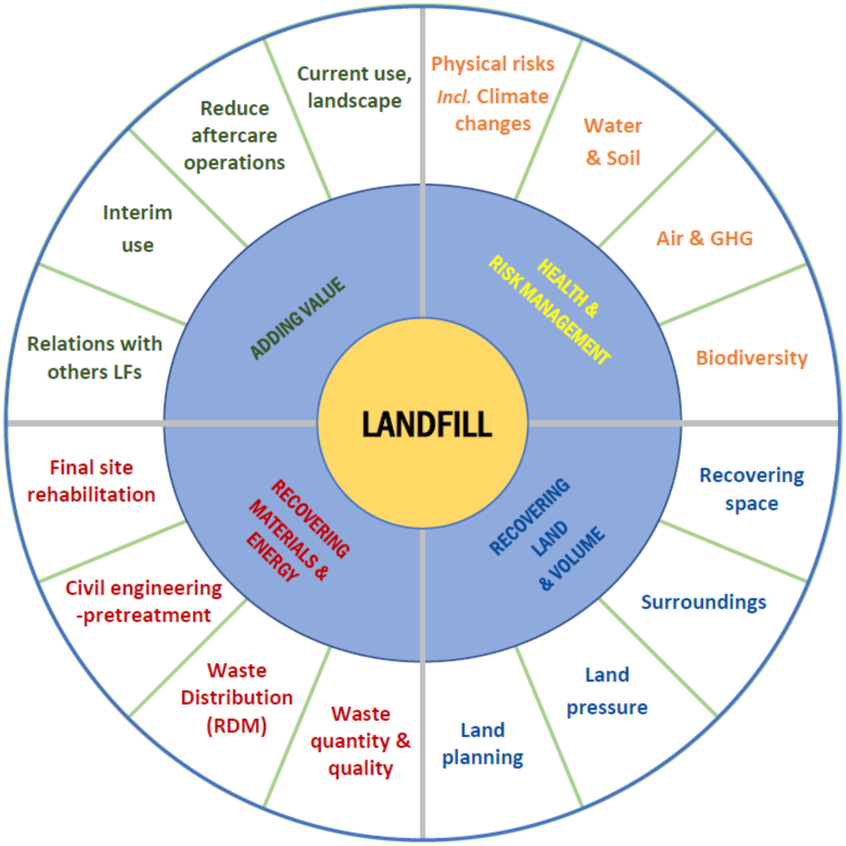
ELIF is used to describe landfills not only in terms of environmental and risk issues but focuses on the quality and the quantity of dormant materials lying on them, to supply relevant data for stakeholders involved in ELFM projects. Regarding remediation issues, we will return to the landfill inventory original philosophy, which is supplying information about environmental and risk issues. ELIF is divided into nine sections, which can supply useful information for remediation studies:

[4] https://www.dov.vlaanderen.be/

- Landfill description
- Waste description
- Environmental form
- Social form
- Technical form
- Economical form
- Additional information
- RDM (Resource Distribution Model)
- Interim use

ELIF cannot only be used for landfill mining or interim use purposes but can also be helpful to design the optimal remediation scheme of the site. The complete filling of a ELIF datasheet related to a given landfill is a great help not only for mining purposes but also for remediation works, whether the landfill will be mined or not. Of course, it implies that the ELIF section has been completed with relevant information following ELIF principles, based on historical studies, site visits, on-site studies and eventually RAWFILL multi-methods geophysical imaging. Filling the ELIF is an iterative process, and it should be completed progressively.

Relevant categories of ELIF parameters for landfill remediation are summarized in **Figure 3** and listed in detail in **Appendix 2**. For a detailed list and description of ELIF's indicators and definition, please consult the ***Deliverable WP T1.4.1 "List of ELIF indicators"***.




**Collecting suitable data from ELIF database**

*Figure 3 – ELIF : Drivers and indicators.*

Useful information for conducting detailed studies and define the optimal remediation scheme of a landfill can be extracted from the ELIF. Please remember that these data are already a synthesis of prior observations and survey, so the analysis of raw information can also be fruitful if it is possible to retrieve it. Please also remember that sometimes raw information can be outdated, for example a 20-year-old analysis of pollutants does probably not fit the current standards anymore and so will be of poor help. Finally, please note that the current site situation may have evolved within time, for instance regarding leachate, air emissions and stability.

Some rules of thumbs can be applied, i.e.:

- Production of biogas from domestic waste in intend to drastically reduce and even disappear after 30 to 40 years of post-management, depending on the waste, the presence of water and the landfilling conditions;
- Production of leachate will also decrease if a capping with a certain level of watertightness has been installed;
- Stability of the waste mass is supposed to increase within time, although external factors can change the situation so that an up-to-date observation of the slopes shapes and surface cracks is always welcome;
- Settlement should decrease within time, although they can last several decades with a nearly constant rate.

- Reopening a landfill to place waste, even aged ones, in open air and under atmospheric conditions again may reactivate them and lead to new degradation processes with consequent releasing of gases and leachates. This must be considered during the remediation design.

Please note that sometimes the absence of an indicator does not mean that it does not exist. Maybe there are no visible leachate around the waste mass, but maybe there are some local aquifers within the waste, that can be released during the works.

**Decision Support Tool 1 - Cedalion**

After filling the ELIF with all the data available, the Decision Support Tool (DST) 1 - Cedalion can be used to analyse this large amount of information, thereby detecting the most promising landfills in terms of valorisation potential and project feasibility. The result of the Cedalion tool is a guidance to the next level and hence is not simplified to a yes/no decision. The result will be a ranking for different possible pathways: (i) waste-to-materials, (ii) waste-to-energy, (iii) waste-to-land and (iv) interim use. In the first place, RAWFILL introduced this method in view of large scale prospecting campaigns. However, if the user is not evaluating a database with that many landfill sites, the Cedalion tool will also provide results for an individual landfill. Furthermore, landfills can obtain a'quick response that indicates the start of setting up a long-term management plan wherein ELFM might be an option. Furthermore, it detects the landfills for which an urgent solution is necessary because of future potential ecological risks, the solution can be either a landfill mining or rehabilitation project. This approach is in line with the concept of Dynamic Landfill Management which aims at a long-term active management of landfill, going beyond containment measures.

By means of this prioritization and classification, DST 1-Cedalion can identify the landfills for which it is worth investing in more detailed characterization by means of geophysics and targeted waste sampling. The results of these investigations can be used as input for the second step of the two-step DST: Orion (*see below for more information*).

Following RAWFILL methodology, there are several ways to collect on-site data relevant for ELFM project study:

- Organization of a detailed site visit to specify and plan further interventions;
- Multi-imaging geophysical survey (see the Landfill Miner Guide);
- Targeted waste sampling based on the results of the geophysical survey: definition of locations for trenches and/or boreholes to validate the geophysical model (see Deliverable WP T1.3.1 SWOT Analysis of landfills investigation methods);
- Log of the waste based on RAWFILL method for visual waste characterization on-site (see Deliverable WP T1.3.1 SWOT Analysis of landfills investigation methods);
- Laboratory tests, especially description of waste for several meshes (see Deliverable WP T1.3.1 SWOT Analysis of landfills investigation methods: standardized waste description);
- Eventually, based on results of waste sample analysis and description, a new interpretation of the geophysical results or a second geophysics survey (this can indeed be an iterative process).

Then, based on the relevant information collected above, building a Resource Distribution model is the next step to get a better overview of the landfilled resource available and the opportunity to launch or not an ELFM project.

**Building Resource Distribution Model**

The Resource Distribution Model (also called RDM) is a 3D view of the landfill where the resources available within a landfill are mapped. It is built based on the correlation between geophysical data and waste samples (boreholes and trenches). Building a RDM has several advantages:

- It provides a better comprehension of the landfill site, especially for old and poorly documented landfill where the geometry and the waste content were unknown.
- It is the best way to calculate the volume of the waste content within the landfill.
- It is very helpful to set up an ELFM project and its technical feasibility.
- It is a powerful tool to identify lateral variation in terms of waste composition.

For more information regarding the RDM and its building, please refer to the Landfill Miner guide and RDMs of the RAWFILL Pilot sites.

#### Decision Support Tool 2 - Orion

After collecting more detailed information by using geophysical exploration methods and building a Resource Distribution Model, the second Decision Support Tool - Orion can be used. This is a dashboard consisting of several open access tools related to landfill mining or dynamic landfill management, each with its own strengths and weaknesses. RAWFILL has identified several decision support systems in order to integrate them in an overarching DST. Behind the dashboard, a roadmap is included to guide the user towards the most suitable tools to apply depending on the possible outcome for a landfill in terms of valorisation potential. This guidance is based on a couple of straightforward but more complex questions regarding the characteristics of the landfill. It will help the user with estimations about the feasibility of a business case, the necessity of a remediation project, simulating certain scenarios or finding sustainable interim solutions. The latter, interim use, is a quite new concept. It provides to the landfill a new function that is beneficial for nature and/or society while bridging time until a better valorization might be profitable. Interim use can go from one year (e.g., energy crops) up to several decades (e.g. solar panels).

### 2. Landfill remediation project conceptualization

#### Step I: Find project partners

The success of remediation projects is dependent on numerous aspects, ranging from economic viability, environmental/ecological impacts, to stakeholder engagement. In the soil remediation sector, a conceptual site model (**Fig. 4**) is often used. Such a model provides a simple visual insight into the properties of the site and the environment. The advantage is also that gaps in knowledge can be detected and indicate the places where more information is required. In addition, it is easier to identify and further describe the relationships between the environmental and socio-economic aspects.

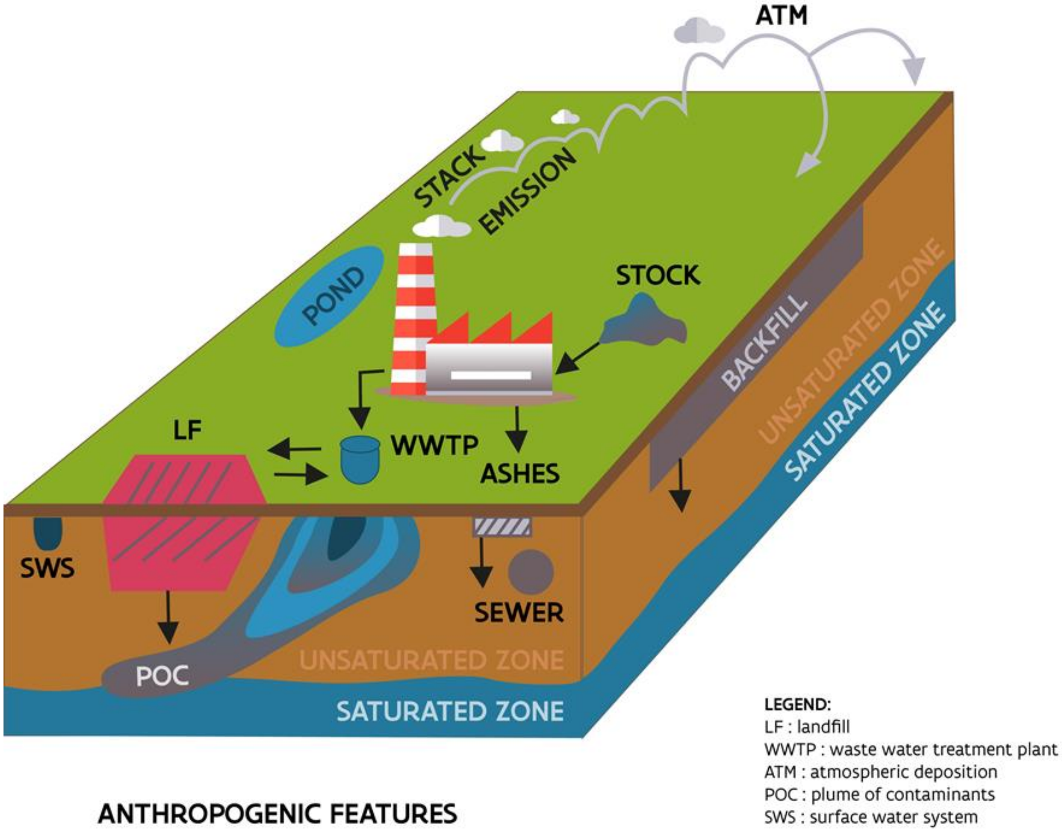



*Figure 4 - Conceptual site model (REGENERATIS, 2020).*

Identifying the different stakeholders and their needs is a necessary step in any project, but particularly important to enable a sensible ELFM implementation due to the impact stakeholders can have on the execution of an ELFM project. Some of the major stakeholders involved in ELFM projects include landfill owners, governmental institutions, technology providers, local communities as well as energy and production companies. The stimulating or hindering influence of a stakeholder is mostly determined by how their needs are addressed. These needs are the expectations and requirements that the stakeholders have towards the project's implementation.

**Step II: Communication**

Stakeholder management is based on a systematic approach of identifying, managing, controlling and communicating with different parties who may affect or be affected by a project. Despite the presence of many blueprints on how to conduct stakeholder management, it is at its root a social endeavour and thus will require tailoring to the unique situations faced by an individual project.

ELFM projects entail a high degree of complexity at several levels and functions. The use of the conceptual site model and following scheme (**Fig. 5**) are helpful to check out the roles, levels, timeframes, and expectations, among others, of an ELFM project.

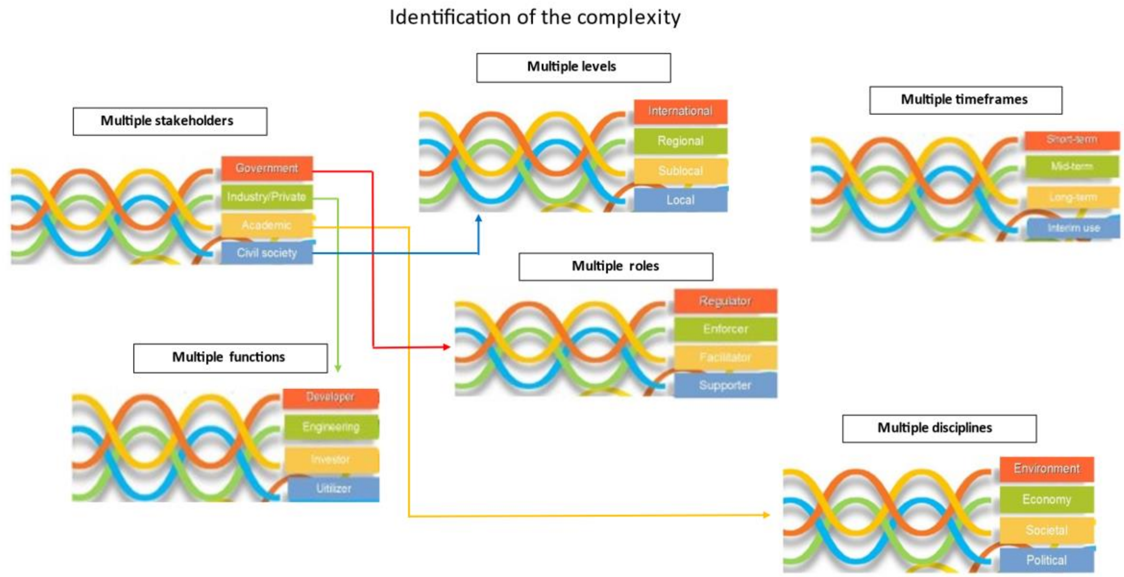



***Figure 5 - Identification of the level of complexity of a project (Wille, 2015).***

Based on discussions and further data collection, update the conceptual site model and introduce the relations systematically and links to the broader system around the landfill. Identification of the stakeholders is only one of the critical components; information and communication are the next building blocks in a successful outreach.

Keep in mind that an ELFM project is a time-consuming process and the timeframe between first exploration and the start of the landfill redevelopment/mining project often takes five years or more. Setting up a communication strategy is necessary and a clear process description points out the timeline from the earliest stage. The brownfield covenant process (**Fig. 6**; see section 2.3.4 for more information regarding the brownfield covenant) illustrates this timeline.

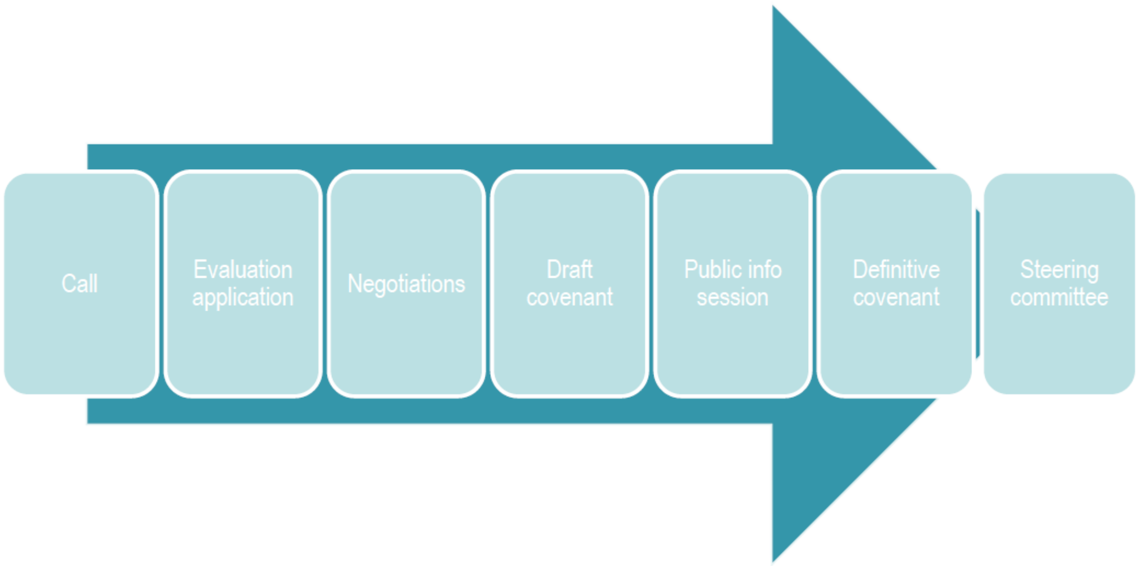



*Figure 6 - Brownfield covenant process timeline (Miseur & Wille, 2014).*

In this context, a neighborhood dialogue is an essential and effective instrument to avoid environmental conflicts that affect the smooth running of the project. Neighbourhood dialogues are voluntary structured long-term communication processes in which stakeholders, neighbours and the competent authorities meet face-to-face. A neighbourhood dialogue can be seen as a proactive instrument of conflict management and crisis prevention. Its aim is to prevent (or resolve if necessary) environmental conflicts by balancing the stakeholder's interests and by improving the environmental performance of ELFM project (IMPEL Network, 2007).

Fundamental tenets of the communication strategy can be summarized as:

- Think broadly when identifying your stakeholders;
- Initiate contact at the earliest opportunity;
- Understand the concerns or expectations of each stakeholder;
- Maintain the stakeholder management plan as a living document. Update regularly and when the project enters a new phase.

**Step III: Cost and benefit analysis**

Although this is not the purpose of the project, the ELIF supplies a very simplified method for estimating the cost of the ELFM option, based on the quantities of waste materials that can be recovered. The cost calculator can be found in the ELIF "waste description" section and is based on a simplified or detailed waste composition. For each type of waste, the quantification of the volume and the density must be given in order to calculate the weight of landfilled waste. These data are provided by the Resource Distribution Model. Then, evacuation costs will be calculated as well as recovery costs that can be negative (you must pay) or positive (you receive some money for the selling waste materials). To evaluate the evacuation cost by rail, boat and trucks, RAWFILL supplies a dedicated GIS map[5] and a

5 Only valid for Wallonia for the moment but other tools exist and are referenced in the DST 2-Orion/transport system.

door-to-door cost simulator tool[6]. The total balance is then calculated and will give a first idea of the profitability of an ELFM project. Based on that a business case can be developed. For that purpose, RAWFILL recommends the use of OnToL, one of the tools mentioned in the DST 2–Orion.

**Step IV: Sustainability study**

When assessing different potential project outcomes or rehabilitation concepts, one should take into account more than just the economic considerations (e.g. cost-benefit analysis). It is important to assess the added value of the project to the society. This can be included in the project planning by means of a sustainability assessment. Such assessment should take into account if there is any new job creation, if the project contributes to the improvement of the neighbourhood (e.g. by creating space for nature or recreation by means of playgrounds) or reduction of greenhouse gases generated by the landfill.

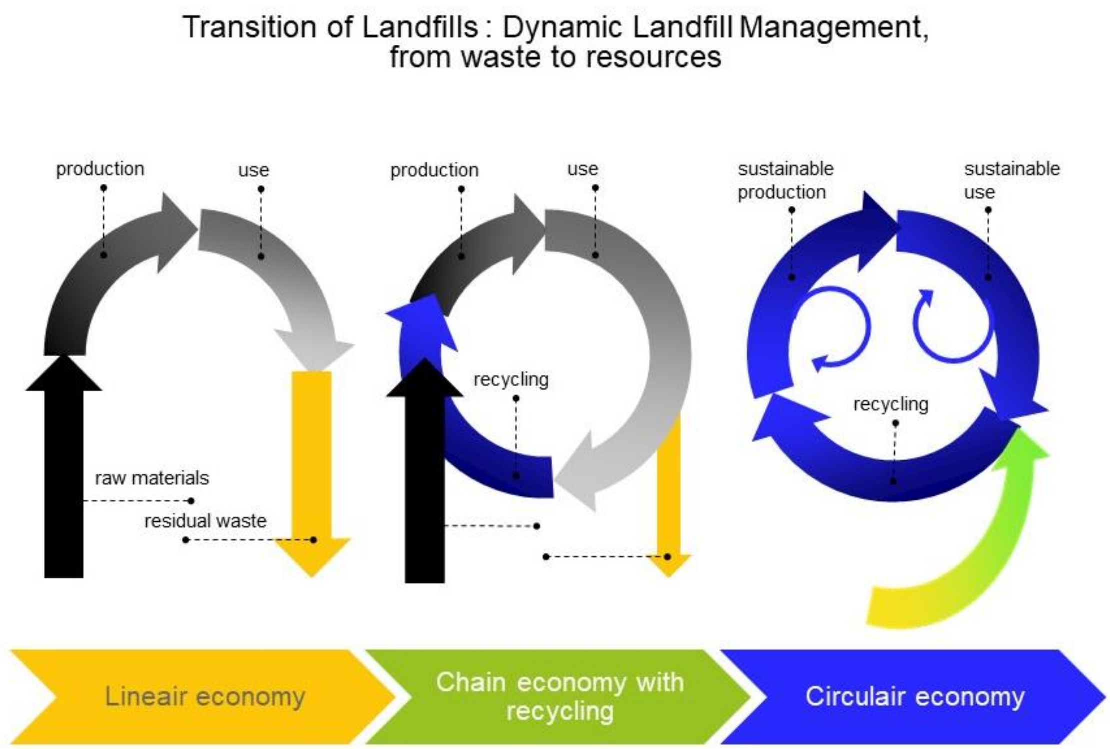



*Figure 7 - Dynamic Landfill Management: from waste to resources (COCOON project, 2018).*

Considering the approach of Dynamic Landfill Management (**Fig. 7**), the redevelopment of landfills should be performed in a way that the landfill becomes an integrated part of its dynamic environment. When implementing Dynamic Landfill Management, one should take into account the limitations and opportunities that are applicable on a certain landfill site. Opportunities can be detected on a national, regional or local policy level. These opportunities can align with policy goals from different sectors. E.g. in Flanders, a round table was organised with different governmental authorities, to discuss the possible potential of landfills within their specific policy goals. This

6 Available only for trucks and train transportation for the moment.

could go from water protection/storage to needs for renewable energy or from afforestation to sustainable agriculture.

Landfill redevelopment opportunities can be translated in different ways, sometimes complementary to each other and always depending on local policy, time, market value, environmental issues, neighbours interest and techniques available.

The landfill remediation and/or redevelopment project requires an upstream preparation and therefore it should be carefully planned based on the opportunities identified. The feasibility of a landfill mining project will strongly depend on the volume of waste materials and its value, its potential for energy revalorization and the land pressure around the site. When the landfill is not of immediate interest for ELFM, a temporary function (interim use) can be implemented to reclaim the land occupied by the landfill (e.g. installation of solar panels, energy crops, recreational use, nature redevelopment). When the value of materials or land pressure increase, a reassessment of the landfill mining opportunities should be done in order to see if optimal ELFM conditions are met. In some cases, the interim use option will be the final use of the site. The interim use should be chosen in a way that respects the surroundings and the environment. When the landfill is a potential threat to human health and the environment, traditional landfill rehabilitation (i.e. landfill capping) should be made prior to the development of an interim use. Of course, it should be carefully designed so as not to aggravate the situation and to minimize all nuisances affecting the residents (traffic, noise, dust, odors, etc.). Finally, landfills with no strategic location or low value content can be left for natural conservation as long as a landfill does not represent a risk to human health and for the environment. In that case, no action is taken on the landfill.

Depending on the geographical location of the site, the variation of landfilled waste composition, but also depending on strategic positions in relation to a probable increase in material/land values in the near future, a combination of landfill mining/interim use/site redevelopment may be considered to conceptualize the rehabilitation of the landfill.

Today, as the trend is to change the approach to landfill post-management (nature restoration, green electricity, ...), it is very interesting to consult existing databases to find suitable landfill sites to develop landfill mining, interim use or redevelopment project on them.

## 3. Landfill sustainable project development

In the context of landfill mining or landfill rehabilitation, systematic project planning should be a transparent, deliberate and coordinated effort in order to identify and manage all relevant aspects, issues and uncertainties in the frame of the project. Important factors that should be taken into account in the planning process are: (i) the budget (including contracting mechanisms), (ii) the schedule and timeframe, (iii) the availability of staff and support personnel, (iv) the state and quality of scientific and technical knowledge, (v) the availability of technology and equipment and (vi) regulatory and programmatic requirements. The planning action plan will strongly depend on the best solution found for the landfill.

In the planning phase, the final project concept will be worked out in detail, including specific plan designs for the actual implementation of the project (e.g. remediation project, spatial implementation plan, building plans, etc.). As RAWFILL is oriented towards resource, energy and land recovery, the following sections focus on the landfill mining aspect of the planning process. More information can be found in the Landfill Miner Guide.

### Scope statement, quotations and procurement planning

In this phase, the (technical) specifications and requirements of the specific plan designs are included in the scope statement, which is sent to relevant contractors. Subsequently, the quotations will be evaluated based on its content as well as on the contractual and financial specifications included in the documents.

For landfill mining projects, these documents should include technical descriptions of all the works that will be performed on site:

- Preparation works;
- Identification of specific ELFM procedures (e.g. works with biogas and leachates, excavation of waste, transportation of hazardous waste);
- Organisation of the lorry movements inside the landfill where space and mobility for heavy trucks can be limited;
- Organisation of the lorry movements outside the landfill;
- Waste excavation;
- Rainwater, biogas and leachate management;
- Waste sorting and/or pre-treatment;
- Containment of residual waste or waste to relandfill for valorisation in the future (Optional);
- Backfilling with suitable materials (treated waste or exogenous materials as soil);
- Eventual surrounding soil and/or groundwater decontamination;
- Reshaping the site;
- Cleaning;
- Redevelop biodiversity, ecosystem services and social added value.

**Excavation phase**

The planning of the excavation phase is one of the most important steps of a landfill mining project. For this phase, it is essential to describe which civil engineering machines (e.g. excavators, trucks, bulldozer) should be used to remove and excavate the waste. This will depend on the waste type and characteristics, which are described earlier within the project, by means of the historic desk information study, the targeted waste sampling and most importantly the geophysical investigations which have been translated to a Resource Distribution Model. The excavation method should also be defined (e.g. bulk or selective excavation) by taking into account the waste composition and its degree of heterogeneity. Furthermore, the waste excavation plan should include punctual measures of different waste parameters like volume, density or composition, in order to ensure conformity with the expectations prior excavation.

Other important aspects that should be considered in the excavation plan, are the management of biogas and volatile organic pollutants, as well as the management of rainwater and leachate. As these two processes can cause substantial risks to human health and the environment, it is especially important that the effects are anticipated by measures foreseen on site in order to protect the on-site workers as well as the inhabitants. The same principle applies to possible stability issues during the mining process as a result of the use of heavy vehicles, vibrations, alteration of water tightness, creation of new slopes, etc.

Another important aspect is the project duration. Depending on the volume of waste to excavate and the nature and biodiversity law applicable on site (if any), local authorities might require that excavation should be divided in several subphases to either reduce the lorry frequency or protect the fauna and flora on site. For instance, the decrease of lorry frequency can reduce the noise and dust associated. Regarding the fauna protection, it is, for example, forbidden to cut trees during the nesting period. Additional rules might be applied depending on the type of fauna and flora present on site. All these requirements can significantly increase the duration of the landfill mining project. However, the increase of project duration can be positive in some cases as it can lead to an increase the percentage of waste recovery by avoiding an overloading of the waste treatment plant capacity.

**Waste valorisation**

Important aspects that should be integrated into the planning of the waste valorisation are the pre-treatment of waste, its processing and its final application. First, the final application should be determined in order to choose the most optimal pretreatment and processing methods and machinery. Here, the first step is to determine whether the waste is best suitable for waste-to-energy or waste-to-material. More information about the recovery option per type of waste can be found in the Landfill Miner Guide.

The pre-treatment of the waste can occur on-site or off-site, depending on several factors like the site situation (e.g. neighbours, available space on site), the type of waste and the modalities for recycling and valorisation and the type of facilities that are necessary for pre-treatment. Furthermore, all mechanical processes and/or machinery that will be used to pre-treat the waste, should be described in detail.

The traceability of waste material and excavated soil or materials must be ensured from their landfill site to their final product, passing, if necessary, through treatment centers or temporary storage sites. Existing regional legislation determines the quality control of secondary raw materials and the traceability of their movement.

**Relandfilling**

During a landfill mining project, not all excavated waste will be recyclable and hence, it will not be possible to valorise some waste to either energy or materials. The evacuation of this non-recyclable waste can be very expensive and therefore, it can be a solution to relandfill these waste deposits directly on site. This should be considered in the project design, as this will require specific organisation as well as authorization, depending on the legislation of the country in which the project is performed[7]. The decision for relandfilling or reusing waste on site, should be made prior to the landfill mining activities, so that the different waste streams to be relandfilled can be evaluated, planned and managed. This will ensure a maximum reuse of low-value materials on site. Void spaces that are created during the landfill mining operations can be filled up, effectively reducing the costs of the project (in case of low-value non-hazardous waste materials). The type of waste that will be relandfilled is important to assess the costs and consequences of this activity for the redevelopment of the site, as relandfilling of hazardous waste will have many implications such as intensive and long-term environmental monitoring, increased costs and the necessity of more complex permits.

The type of relandfilling should be decided and described before the launching of the landfill mining project. Mainly, there are two options for waste deposits to remain on site: reuse by means of backfilling and waste containment. For backfilling, there are some strict geochemical and geotechnical criteria to which the backfilled waste streams need to apply, which need to be taken into account within the design plan of the project (e.g. long-term stability, reactiveness). A plan should be made as well to collect the leachate coming from the backfilled waste to enable and ensure its treatment. In case of the second option: waste containment, a detailed description and map of the waste containment cell(s) is required. This should include the following information: design of the cell, in terms of occupied areas, storage of different waste types in different cells, the location of the cells, their vertical extent. This

[7] Relandfilling is forbidden in some EU regions and countries.

information should be considered in the view of future mining potential, taking technological development and market changes.
Lastly, traceability of backfilling must be ensured and organisation of the lorry movements outside and inside the landfill must be defined.

**Reshaping the site**

The choice to reshape the site after landfill mining activities depends on multiple aspects, including the redevelopment plan for the site and its associated land use, the natural topography of the site, the financial balance of the project and the presence of high value ecosystems or biodiversity. As already mentioned in Section 2.2, it is important that the reshaping concept and plan are discussed with all stakeholders and with the residents living in and around the area, and that it is in line (and supports) the development plan for the site.
Besides a plan for the spatial reshaping of the site, it is important to assess the possibilities taking into account the type of materials that will be used to reshape the site or to restore the topography. To do so, different options can be considered :

- Reuse of the soil-like materials on site (e.g. obtained after sieving the excavated waste);
- Reuse of non-valuable and non-hazardous waste or inert construction waste collected in the vicinity;
- Importation of ground/soil/material from another landfilled site.

The choice for reshaping material will influence the reshaping plan as well, as the different possibilities will have different geotechnical and geochemical characteristics. The costs of the different options are also important and need to be assessed. In some regions, using excavated soil from other sites can be a good opportunity to generate financial incomes and to ensure the economic viability of the landfill mining project.

Lastly, the necessity of a topsoil layer (and its thickness) to cover the reshaped or backfilled site, should be taken into consideration. This will depend on the type of materials that will be used for the reshaping and the future activities that will be developed on site and its corresponding land use (e.g. residential, commercial, industrial, green space). Additionally, vegetation restoration should be defined in the development plan.

**Permits**

In parallel with the planning phase and prior the landfill mining operations, it is important to check that all authorisations and permits have been issued regarding the landfill, waste transportation and waste valorisation for the specified period. As landfill mining is a rather new concept, most of the NWE waste/landfills/soil/environmental regulations are not fully adapted for this kind of operation. Adaptation of the legislation or specific derogation can be discussed and arranged with the competent regional authorities. Regarding the interim use redevelopment project, permits will be also required to allow the implementation of new project on an old landfill.

In Wallonia, for instance, prior to a project, it is necessary to introduce a demand of permitting. Two types of permits exist: the environmental permit and the so-called “permit unique”. The environmental permit aims at protecting the human health and the environment against inconvenient that a project might cause directly or indirectly during the duration of the work operations and after the implementation of the project. The second type of permit so-called “permit unique” is only required if the project requires an environmental permit and urban planning permit. Both permits can be submitted to the local competent authorities at the same time with the “permit unique”. Prior to introducing such operational permits, landfill and surrounding soils must be investigated following the 1996 Walloon

Waste Decree and the 2008 Walloon Soil Protection Decree. For instance, the landfill mining project of Onoz (one of the RAWFILL project pilot sites), a demand for a “permit unique” was submitted. The landfill mining of Onoz was the first landfill mining project in Wallonia. In order to develop other landfill mining project across Wallonia, a Green deal was signed between the Walloon Region, SPAQuE, the local authorities and the private investors. This Green deal was the first one signed in Wallonia and its concept is based on the Green deal from the Netherlands. By signing the green deal, all parties are committed to doing what is within their capabilities to realize the project. It is important to note that the covenant is an obligation of best efforts, not an obligation of result. To succeed in the launching of this ELFM project, a working group was created and met on a monthly basis to discuss technical and legislative issues. The permits to start the ELFM operations at Onoz landfill site was delivered at the beginning of 2021. Moreover, this project will serve as leverage for other landfill mining initiatives in Wallonia.

In Flanders, the principle of brownfield covenants was introduced in order to revitalize and redevelop neglected, contaminated or underutilized sites. Also landfills are included in this approach. By signing such a covenant, the Flemish government offers multiple advantages in terms of administrational and jurisdictional obligations. There are some financial benefits as well. Furthermore, such covenant provides a system in which the communication process with the main stakeholders is facilitated. In that way, existing thresholds for the development of brownfield sites can be overcome. This approach legally anchored in the Decree of 30 March 2007 regarding Brownfieldcovenants.
Following the Decree of 30 March 2007, brownfield redevelopment is defined as a complex process that requires a multidisciplinary and integrated approach in which different aspects such as soil remediation, spatial planning, mobility, communication, financing, etc. should be coordinated (see **Appendix 3**). Furthermore, many actors and stakeholders will be involved. Within a Brownfieldcovenant, the Flemish Government contracts all the actors (e.g. project developers, land owners) as well as the directing authorities or administrations (e.g. the authority who should deliver the permit). The Flemish government gives the approval or disapproval for a brownfield redevelopment project.

Once the project is carefully planned and all the permits are obtained, it is time to start the landfill mining project, remediation project on site and/or interim use project. Depending on the volume and type of waste, in some specific cases, interim use projects can become the final redevelopment project on site. Further information about project execution and aftercare activity can be found in the Landfill Miner Guide.

## III. FURTHER READING

**Amec Foster Wheeler Environment & Infrastructure UK Ltd, BiPRO and Milieu. (2017)**
Assessment of Member States' performance regarding the implementation of the Extractive Waste Directive; appraisal of implementation gaps and their root causes; identification of proposals to improve the implementation of the Directive, European Commission
https://op.europa.eu/en/publication-detail/-/publication/f39af478-8d2e-11e7-b5c6-01aa75ed71a1/language-en/format-PDF

**COCOON project (2018)** https://www.interregeurope.eu/cocoon/

**ENVECO S.A. (2015)**
LIFE12 ENV/GR/000427 LIFE Reclaim "Landfill mining pilot application for recovery of invaluable metals, materials, land and energy"; Technical Report on the inventory of landfills of interests to landfill mining in Greece and selected EU countries, Athens
https://bd1e9349-fa48-4b18-b0b7-98c232f6e999.filesusr.com/ugd/24b53f_a4b680ca794e44d698b585bdee3903d3.pdf

**European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL Network). (2007)**
Toolkit neighbourhood dialogue and best practice examples of different member states : Establishing neighbourhood dialogue.
https://www.impel.eu/tools/neighbourhood-dialogue-toolkit/

**Joint Research Centre. Marc Van Liedekerke, Gundula Prokop, Sabine Rabl-Berger, Mark Kibblewhite, Geertrui Louwagie, (2014)**
Progress in the management of Contaminated Sites in Europe. JRC Reference Reports, Report EUR 26376 EN, European Commission.

**Neculau, C., De Rijdt, R. (2017)**
Enhanced Inventory Framework for landfills within RAWFILL project concept. 16th International Waste Management and Landfill Symposium, Sardinia 2017
https://www.nweurope.eu/media/3966/paper-rawfill-sardinia-2017-829.pdf

**Swedish Environmental Protection Agency. (2002)**
Methods for inventories of contaminated sites: environmental quality criteria guidance for data collection, Report 5053, 138 pp.
https://www.naturvardsverket.se/Documents/publikationer/620-5053-2.pdf

**Behets, T., Umans, L., Wille, E., Bal, N., Van Den Bossche, P. (2013).**
Landfill mining in Flanders: Methodology for prioritization. 15th International Waste Management and Landfill Symposium, Sardinia 2013.

**Neculau, C., De Rijdt, R., Wille, E. and the RAWFILL Team. (2019)**
RAWFILL project: innovative characterization of landfills and smart decision-making as part of the circular economy. 17th International Waste Management and Landfill Symposium, Sardinia 2019.

**Miseur, K., Wille, E. (2014)**
Brownfields in Flanders transversal policy and integrated area development. Conference proceedings CABERNET, 4th International Conference on Managing Urban Land, Final Conference of the EU FP7 Project "HOMBRE"
In cooperation with the EU FP 7 Projects "GLOCOM", "Greenland" and "TIMBRE

**OVAM. (2003)**
Leidraad Brownfield Management / Guidelines for brownfield revitalization in Flanders. Publication prepared by the first Brownfield steering committee Dec. 2001 – Nov. 2003.

**OVAM. (2013)**
Determination of the potential of Landfill Mining and the need for remediation of landfills in Flanders Final report May 2013
https://www.ovam.be/sites/default/files/atoms/files/Landfill-Mining-Final-Report-May2013-DEF-versie-EN.pdf

**RAWFILL project partners. (2021)**
RAWFILL Enhanced Landfill Inventory Framework Deliverable WP T1.1.2 Benchmark of LFM initiatives. https://www.nweurope.eu/media/5608/201902_wpt1-21-rawfill-lfm-experiences.pdf

**RAWFILL project partners. (2021)**
The Landfill Miner Guide. https://www.nweurope.eu/media/13061/rawfill-landfill-miner-guide.pdf

**RAWFILL project partners. (2021)**
RAWFILL e-learning tool: https://www.rawfill-elearning.eu/en/

**RAWFILL project partners. (2021)**
RAWFILL infographic**:** https://www.rawfill-elearning.eu//assets/documents/Rawfill_e-learning_tool_infographic.pdf

**REGENERATIS Project (2020)**
https://www.nweurope.eu/projects/project-search/nwe-regeneratis-regeneration-of-past-metallurgical-sites-and-deposits-through-innovative-circularity-for-raw-materials/

**Wille, E. (2015)**
Brownfield revitalization in Flanders. Role and experiences of the OVAM. Seminar town development and heritage protection. Including presentation 'Town development and revitalization of brownfields in Flanders: multiple aspects of governance', Gdansk, 2015.

**Wille, E. (2016)**

Sustainable stock management and landfills: introduction to Enhanced Landfill Management & Mining (ELFM²). In: Proceedings of the 3rd International Symposium on Enhanced Landfill Mining. 8-10 February 2016, Lisboa, Portugal, pp. 30-49.

**WHO**
Urban redevelopment of contaminated sites: A review of scientific evidence and practical knowledge on environmental and health issues. https://apps.who.int/iris/bitstream/handle/10665/340944/WHO-EURO-2021-2187-41942-57585-eng.pdf

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# APPENDIX

## Appendix 1 – A few definitions

Interim use: temporary land use of a landfill site until landfill mining conditions become suitable (e.g. land pressure, market price, landfill stability). Interim use can be done from a few years (e.g. energy crops) to decades (building of infrastructure, solar panels). In some specific cases, interim use can be the final land use of the landfill site.

**Waste-to-Energy (WtE)** : the possibility of recovering energy in the form of electricity or heat from the thermal decomposition of waste is examined. Here again, the characteristic of the waste is important to take into account (the lower heating value;, the water content and the organic matter content).

**Waste-to-Land (WtL)** : it can be the best option to ensure a good financial viability of the landfill mining project, but the land recovery concept is highly depending of the site localisation, the landfill characteristics et local market factors.

**Waste-to-Materials (WtM)** : the state and the type of concerned materials are the key to assess the potential of waste revalorization. The waste content and its proportion in valuable materials, but also helps to choose the best way to revalorize them.

### Appendix 2 – ELIF most relevant indicators

Generic Information

Age of the datasheet creation and maintenance will give an idea of the content: a 25 years-old data sheet will probably contain less suitable information than a very recent one; although some ELIF inventory can nowadays still be fed by old information.

Landfill ID Card

This section gathers all administrative information related to the landfill described in the data sheet.
Here can be found the following important information:

- **Ownership of the site**
- **Landfill operators**
- **Legal status of the landfill**.
- **Permits and authorizations**.
- **Landfill type:** the most relevant information will be the possible presence of hazardous waste that can lead to more severe remediation methods. On the contrary, an inert waste landfill containing earth and construction waste may not require so many works to be properly remediated
- **Landfill status and dates**
- **Landfill monitoring**
- **Remediation cost**
- **Warranties**
- **Studies**
- **Samples:** all available analysis should also be reinterpreted regarding current state of analysis (contaminants and their related thresholds).
- **Historical information**

Surroundings

This section is related to the surroundings of the landfill, mainly its physical environment and sustainability aspects.

- **Land planning and territorial strategy aspects:** depending on the type of projects (agriculture, housing, industry, etc.), remediation requirements may differ.
- **Current use:** it is quite clear that the current use of the landfill can compete in some cases with the remediation process.
- **Occupation:** type of nearby human occupation (especially housing and industry) may determine relevant scenarios for risk studies of the site and influence remediation operations (gas and leachate control, noise and vibrations, traffic, etc.)
- **Land pressure:** is an indicator of the amount of money that can reasonably spent for remediation
- **General risk evaluation:** will be considered in the remediation process in a way that the identified risks sources will be definitely suppressed. .
- **Environmental issues (specific issue, surface water contamination, geological context, and groundwater vulnerability)**
- **Social support:** this indicator is related to the current use of the landfill by people, especially local people who may not be interested by a remediation reducing the services they get from the landfill site (walking, biking, etc.).

- **Biodiversity:** all damages to surrounding or in-situ biodiversity must be avoided and, if not possible, compensation measures will be taken.
- **Access for landfill mining operations** is also interesting to define what kind of machines can be brought on site for remediation operations
- **Facilities for waste valorization and treatment:** this indicator is not truly relevant here, except if some waste must be removed from the site during remediation process (for instance, discovering tanks of hazardous chemicals).
- **Leachate treatment plant on site or nearby:** it may happen that some extra leachate produced during remediation works must be eliminated.

Landfill geometry

Regardless the nature of waste, this section describes the geometry of the landfill and the associated construction elements/infrastructures/structures that can be found on the site.

- **Landfill morphology** will determine how reshaping and remediation can be performed, the nature of materials and geosynthetics to use, for instance of steep slopes, the way to manage rainwater properly, etc.
- **Waste heights/depth**
- **Fragmentation** (the fact that waste can be spread in several separated locations)
- **Stability of the waste mass**: first, an unstable waste mass leading to a serious risk of global landslide and collapse must always be secured, which represents usually heavy costs. Then, local instabilities must also be carefully studied before remediation.
- **Top layer**: the presence of a capping is obviously an indication that remediation works have been performed and that the risks of negative impacts from the waste are drastically reduced.
- **Bottom layer:** coupled with the geological context indicator, the nature of bottom layer (watertightness and drainage capacity) will influence the probability of finding contaminating soils, rocks, and aquifers around the landfill, that could require remediation operations.
- **Emission to air:** biogas, industrial gases, sometimes dust, etc.
- **Biogas aerial collection system**.
- **Erosion problems**

Landfill waste

This section gathers all suitable information about the wastes buried in the landfill.

- **Dates**
- **Main type of waste**
- **Specific waste streams**: some specific landfilled streams as asbestos, construction waste, dredging sludges, slags, contaminated soils, etc. may induce specific remediation requirements especially in case of mono landfills.

  **Hazardous waste, radioactive waste, hazardous hospital waste, military waste and asbestos** may require specific precautions regarding studies, especially during drilling operations, and subsequent works.
- **Main physical state of the waste**
- **Presence of leachate**.
- **Waste composition**: among the indicators, presence of water and gases are the most important regarding landfill remediation.

<u>Interim uses</u>

Some interim use indicators can be helpful for remediation works and studies, as:

- Surface state: a rough surface will require reshaping and levelling works, and a surface covered by trees will require some analysis of the ecological value of the trees before deciding to cut them
- Thickness of top soil: a good agronomic soil is a precious and non-renewable resource. It must be carefully removed and stored for further use, for instance a new capping.
- Slope angle: the value of the landfill slope will influence the capping type that can be placed

## Appendix 3 – Brownfield timeline (OVAM, 2003)

| Phase | Intermediate steps | How? | Who? |
|---|---|---|---|
| **I INITIATION PHASE** | 1. Exploration | Step 1:<br>gathering information<br><br>Step 2:<br>organising brainstorms<br><br>Step 3:<br>organising project management | Initiator |
| | 2. Engagement | Statement of intent | Initiator + stakeholders |
| **II CONCEPTUAL PHASE** | 3. Detailed analysis | Performing studies:<br>- technical-environmental<br>- spatial<br>- economical | Brownfield management, experts, consultants |
| | 4. Developing different rehabilitation pathways | Step 1:<br>Design of different pathways<br><br>Step 2:<br>Cost-benefit analysis of different pathways<br><br>Step 3: sustainability assessment<br><br>Step 4:<br>Final assessment | |
| | 5. Agreement | - concept for rehabilitation<br>- stakeholders<br>- planning | Brownfield management |
| **III PLANNING PHASE** | 6. Specifications and quotations | | |
| | 7. Requesting permits | | |
| **IV PROJECT REALISATION** | 8. On-site works | | Project developer, remediatior |