Interreg North-West Europe
RAWFILL
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Deliverable WP T3.1.3.
DST Performance report

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1. Introduction

The DST performance report demonstrates that the Decision Support Tools (DST) developed in the framework of the RAWFILL project can be used to compare the landfill mining potential of selected landfill sites and rank them. This report is divided in two parts : (1) the testing of Cedalion (DST 1); and (2) the testing of Orion (DST 2). Recommendation to fine-tune the tools are also provided at the end of each section.

2. Decision Support Tool level 1 - Cedalion

The Cedalion tool was created to provide quick answers regarding one landfill site. It also allows to classify the landfill sites based on their landfill mining potential (i.e. waste-to-materials, waste-to-energy, waste-to-land, interim use). The tool was first tested on 3318 landfill sites from the Flemish database. Then, the tool was applied to the RAWFILL pilot sites, 70 landfill sites from Walsols[1] (Walloon landfill database) as well as landfill sites belonging to the advisory board members. The selection of the sites from Walsols is explained in detail in the *Deliverable WP T3.1.2. ELIF performance report*. For confidentiality reasons, only the municipality where the landfill is located, is mentioned.

2.1. Test on 3318 sites from Flemish landfill database

In Flanders, OVAM has created an extensive database including all the old landfills that have ever been identified or inventorised in the region. Currently, it contains 3318 records. This database compiles different information sources:

- the contaminated sites from the OVAM database that have been identified as a landfill;
- old registration forms of landfills (POT-fiches);
- landfill permits;
- inventories based on the analysis of historical maps.

Hence, not only landfills for which a permit was delivered in the past, are included in the database. Also locations where waste was used to fill up old quarries or to elevate the terrain for functional reasons were included. This means that in most of the cases, information about the geometry, type of waste, period of landfilling, etc. is lacking. Therefore, most of the landfills will receive no quick response in the Cedalion DST1. This is visualized in **Figure 1**, which shows the distribution of the number of quick responses obtained per landfill site. 2313 landfill sites received no quick response in the Cedalion DST 1. This corresponds with 70% of the total number of landfills. The other 30% received at least one quick response. 887 landfills obtained one quick response, 87 landfills received two quick responses and only 13 landfills received three quick responses. The remaining four landfill sites obtained four different quick responses. No landfill received five quick responses.

[1] The 70 landfill sites are the same as the ones selected for the testing of the ELIF.

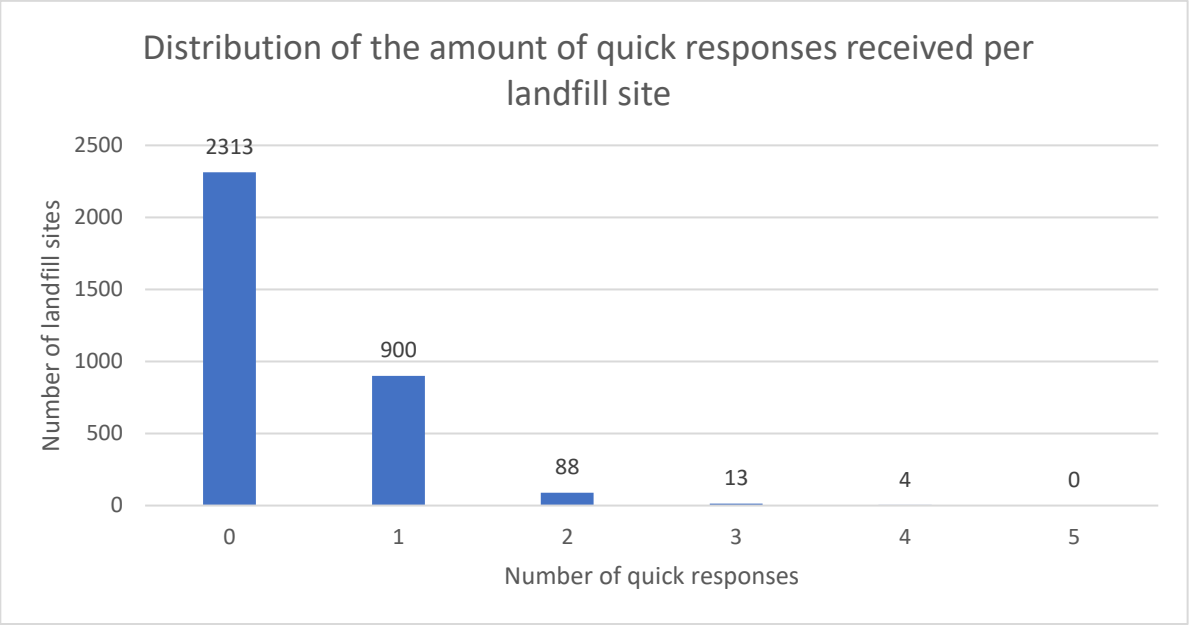

Figure 1: distribution of the number of quick responses obtained per landfill site for the Flemish database of 3318 records.

2.1.1. Overall responses

Figure 2 shows how many sites obtained a certain quick response.

Orion

From 3318 records, 1005 did receive a quick response in Cedalion (30 %). Approximately half of these landfills (56 %) are redirected to the Orion tool because of a high land value/pressure or valuable content. In Flanders, this is an expected outcome because of the overall high population density and the scarcity of space, which results in a high land value and pressure. Only 15 landfills are redirected to the Orion tool because of their valuable content in terms of revalorization of the materials.

Long-term Interim Use (IU)

18 percent of the landfills that received a quick response, receive a suggestion for agricultural development as long-term interim use (e.g. agroforestry). In Flanders, almost half of the total area is used by the agricultural sector, so this is again a logic outcome. In view of ecological agricultural systems, agroforestry can be a good solution. Only 6% of the landfills (58) receives a quick response for nature development as a long-term interim use.

Medium-term Interim Use (IU)

Further, 77 landfills received a quick response to develop a medium-term interim use because of potential ecological disasters in the future (non-inert waste). 67 other landfills also form a potential ecological disaster, but on these landfills a medium interim use is not sufficient: they require an urgent solution. Another 55 landfills require an urgent solution because of potential health-related effects. However, the testing showed that potential health-related effects were not accurate and overestimate due to the simplicity of the questions in the Cedalion. Therefore, this quick response was modified in the latest version of the Cedalion (Cedalion v.1.3).

The remaining quick responses concern other types of medium term interim uses. Nature and agricultural development are the most common. Only a few landfills receive the quick response for the

development of infrastructure or agriculture for energy crops. This can be explained by the lack of information on the type of cover of the landfill and the terrain morphology that is currently present.

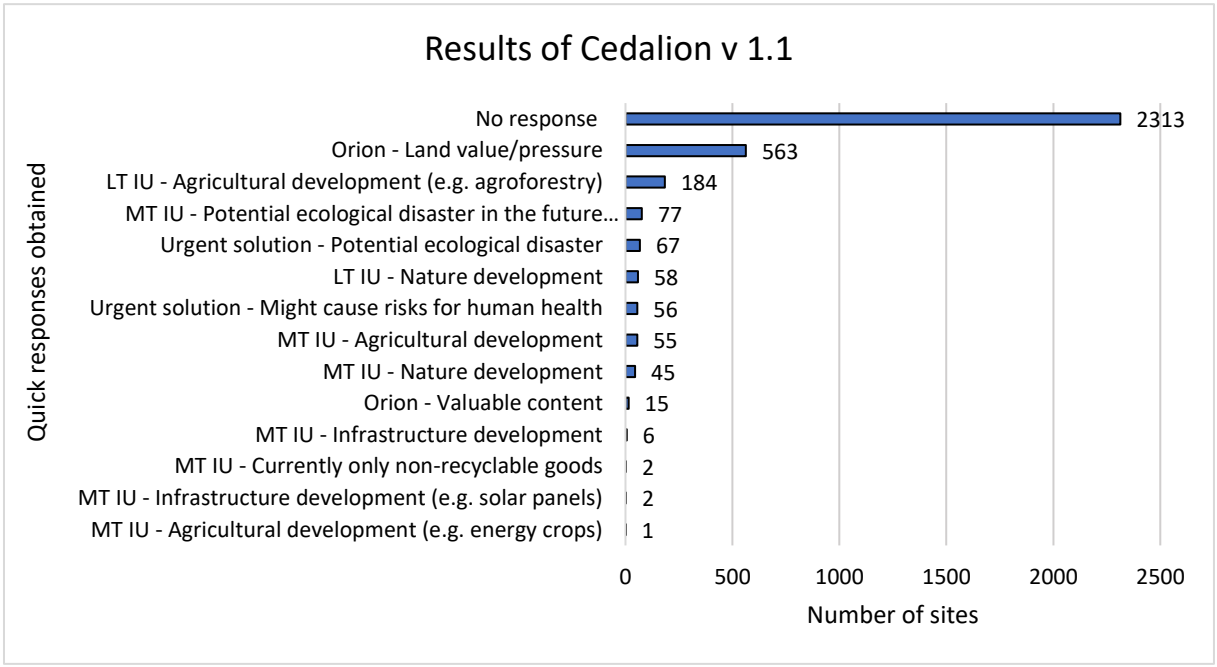

Figure 2: distribution of the number of quick responses obtained per landfill site for the Flemish database of 3318 records.

Using the Cedalion field application to solve the lack of information

Working with large databases comes with certain advantages and disadvantages. On the one hand, it is good to summarize all information in one coherent database. On the other hand, creating large database increases the investment cost of gathering and validating information. For a significant number of the landfills in the Flemish database, information is currently lacking. Therefore, OVAM will keep making efforts in the future to complete, update and validate the data. The Cedalion field application will play an important role in this process in the future, being a user-friendly tool that can be shared with owners, local authorities, soil experts,… In Flanders, all municipalities were already contacted and asked to use the field application in order to deliver information on the landfills that are situated in their municipality. Now we are also including the use of the field application in the soil investigations that will be performed on landfills. In that way, the number of obtained quick responses will hopefully increase and we will have a more overall view of the possibilities for these landfills.

For now, we can start with analysing the 1/3rd of the landfill database for which a quick response was obtained. Furthermore, the ranking scores can already give an idea of the most optimal management option for a landfill: waste-to-materials, waste-to-land, waste-to-energy and interim use.

2.1.2. Case studies : discussion

Landfill nr. 13

This landfill received two quick responses:

- Orion: high land value/pressure
- Medium term IU: agricultural development

The landfill consists of municipal solid waste and industrial waste and was in exploitation before 1955. It is a small landfill with a volume of 3600 m³ over a surface of approximately 4000 m². The landfill is covered with soil and the terrain morphology consists of grass. It is located in a residential area and is used for agricultural purposes (grassland). The landfill can have severe consequences because of its proximity to a drinking water zone.

In **Figure 3**, the ranking scores are visualized for the landfill and can be compared with the average ranking values for the whole dataset. Landfill 13 obtained a very high ranking for the WtL scenario in comparison with the average. This high value is mostly related to the optimal surroundings of the landfill (criteria 6) for this scenario.

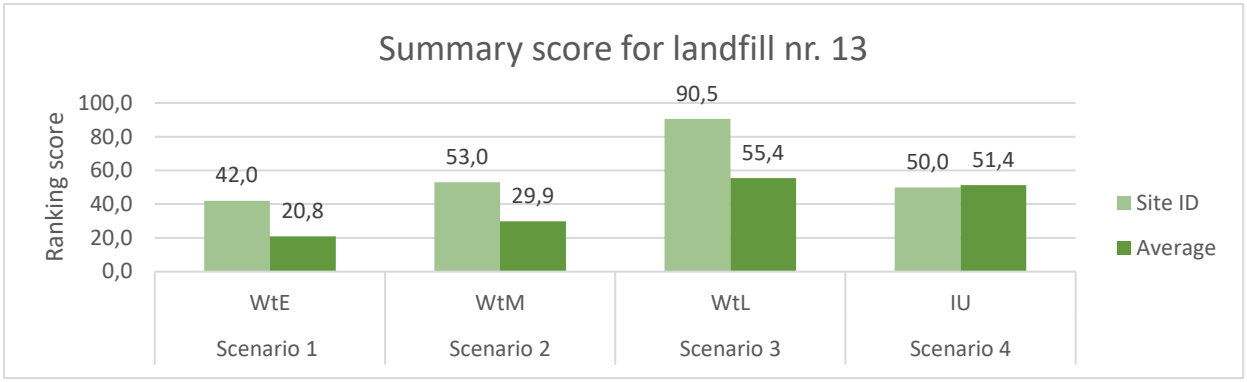

Figure 3: Ranking score obtained for landfill nr. 13.

For this landfill, the waste-to-land scenario seems most optimal. Waste-to-energy or waste-to-materials does not seem to be preferable options. Hence, the interim agricultural use remains a good option until landfill mining becomes viable in the future. That is also what the quick response "medium interim use – agricultural development" suggests. However, because of the high land value/pressure on the location of the site, Orion could be used to further analyse the options of landfill mining in more detail.

Landfill nr. 2300

This landfill was exploited in the period from 1955-1980. The main waste types that were landfilled were municipal solid waste and dredging materials. The surface of the landfill is approximately 12 ha and the volume of the landfill is 778,000 m³.

In Cedalion, the landfill obtained the quick response "Medium term interim use – infrastructure development". The ranking scores for the different landfill mining scenarios are included in **Figure 4**. Compared to the average ranking scores of the Flemish database, landfill Nr. 2300 obtained relatively high scores for the waste-to-energy and waste-to-material scenario. Also for the waste-to-land scenario, the site-specific score is higher than the average one. For the interim use scenario, the score for the landfill is more or less similar to the average score.

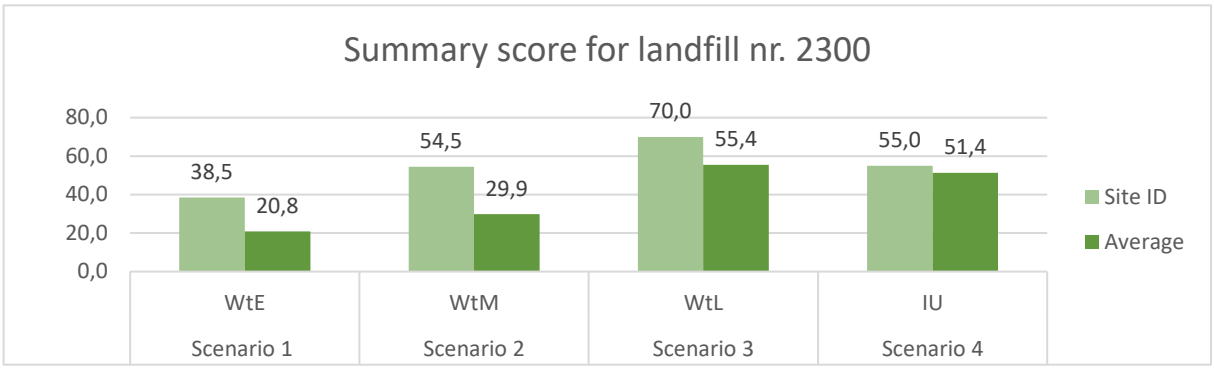

Figure 4: Ranking score obtained for landfill nr. 2300.

Based on the ranking scores for the different scenario's, a landfill mining project seems to be possible. Figure 5 shows the sum of the ranking scores per criteria. The type of waste seems to be suitable for waste-to-energy. Based on the age and large volume of the landfill, the waste-to-material scenario is the preferred one. However, use, accessibility and surroundings of the landfill suggest that the waste-to-land or interim use scenario will be more suitable. The quick response also suggests developing a medium term interim use because of infrastructure development. This response suits with the current use of the landfill: a solar panel farm. At the time when the solar panels were installed, it was probably not profitable to develop a landfill mining project. Cedalion already shows that, based on the characteristics of the landfill, the option to develop a landfill mining project is not excluded. While awaiting better market conditions for mining the landfill, the current interim use (solar panels) gives a sustainable use to the landfill.

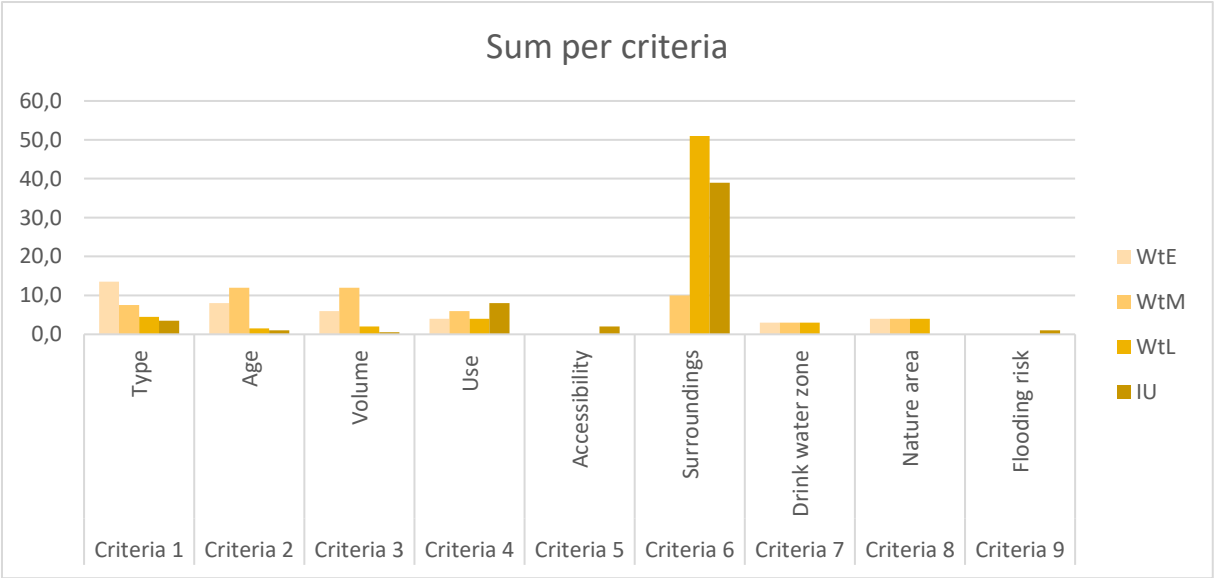

Figure 5: ranking scores for the different scenarios, per criteria.

2.2. Test on RAWFILL pilot sites and landfill sites from Walsols

This testing phase consisted in the following steps:

- Step 1: Testing the coupling between the ELIF and the Cedalion tool.
- Step 2: Testing the coherence of the quick responses obtained for each landfill site.
- Step 3: Reporting to OVAM to fine-tune the Cedalion tool.

- Step 4: Testing the new version of the Cedalion tool.

Step 1 – Testing the coupling between the ELIF and Cedalion.

The ELIF tool was designed to export the data encoded in the ELIF tool directly into the DST 1 – Cedalion. The first step of the testing process was dedicated to ensure the perfect compatibility between the two tools. For that purpose, for each landfill sites, the correlation between each field was checked. This step was performed for every new version of the ELIF and Cedalion tool. The importation of ELIF data into Cedalion allows to fill automatically all the fields present in the Cedalion tool. However, differences in waste composition between the ELIF and the Cedalion can sometimes appear. This happens when the user only filled the "simplified waste description" (spreadsheet "waste description") in the ELIF. For logistical reasons, the correlation of the waste material content in that case is not possible as the user entered manually the list of waste materials present within the landfill, making the automatic coupling for waste content between the two tools impossible. Therefore, we strongly encourage the user to verify all the inputs in Cedalion, especially the type of materials contained in the landfill, before running it.

Step 2 and step 4 - Testing the coherence of the quick responses obtained for each landfill site.

The coherence of the quick responses was assessed based on the current knowledge that we have of the landfill site and its location. The **Table 1** shows the results of the testing for the RAWFILL pilot sites. The testing results of the sites from Walsols are presented in **Table 2**. For each table, we present the results of the two versions of the Cedalion (version 1.0 and 1.1). The quick responses as well as the reasons behind these quick responses are displayed in **Tables 1 and 2**. Critical comments regarding the quick responses obtained is also provided.

					Version 1.0		Version 1.3		
Site	WtE	WtM	WtL	IU	Quick response	Reasons	Quick response	Reasons	Comment
Onoz	44	64	60	79	Long-term interim use	Agricultural development (ecoforestry)			OK
					Orion	Land value/pressure	Orion	Land value/pressure	±[2]
					Long-term interim use	Nature development	Long-term interim use	Nature development	OK
					Medium term interim use	Agricultural development (energy crops)	Long-term interim use	Agricultural development (e.g. agroforestry)	OK
							Long-term interim use	Nature development and conservation	OK
Les Champs Jouault	64	70	54	75	Medium term interim use	Currently only non-recyclable goods	Medium term interim use	Currently only non-recyclable goods	OK
					Orion	Valuable content			OK[3]
					Medium term interim use	Infrastructure development (solar panels)	Medium term interim use	Infrastructure development (e.g. solar panels)	OK
La Samaritaine (Lingreville)	45	76	90	70	Medium term interim use	Ecological disaster	Medium term interim use	Potential ecological risk in the future (non-inert waste)	OK
					Urgent solution (mining)	Ecological disaster	Urgent solution	Potential ecological risk in the future (non-inert waste)	OK
					Long-term interim use	Nature development	Long-term interim use	Nature development	OK

[2] A priori, there is no land value/pressure for the landfill site of Onoz. The quick response obtained is related to the presence of an economic area at the eastern border of the site.

[3] The quick response obtained « Orion – valuable content » was in conflict with the "Medium term interim use - Currently only non-recyclable goods". The problem was solved in the version 1.1.

					Medium term interim use	Nature development	Medium term interim use	Nature development	OK
					Orion	Valuable content	Orion	Valuable content	
							Long-term interim use	Nature development and conservation	OK
Leppe	61	82	95	54	Medium term interim use	Infrastructure development (e.g. solar panels)	Medium term interim use	Infrastructure development (e.g. solar panels)	OK
					Orion	Valuable content			OK[4]
Meerhout	61	64	70	60					
Emerson's green	34	56	93	47.5					
Stockley Park	43	71	125	35	Medium term interim use	Infrastructure development (e.g. solar panels)	Medium term interim use	Infrastructure development (e.g. solar panels)	±[5]

Table 1 – Results of the testing of Cedalion tool for seven RAWFILL pilot sites.

[4] The Leppe landfill contains valuable materials that could potentially be valorized. However, removing this large volume of waste material could generate negative benefits. Therefore, the quick response "Orion – valuable content" in the version 1.1 is only obtained for smaller landfill where the waste deposits are easier to excavate.

[5] The development of medium-term infrastructure could potentially be an option. Nevertheless, Orion – land value/pressure seems to be the most appropriate option as we obtained a high score for WtL (125) and the land value in the London Neighborhoods is relatively high (see section "step 3" for further explanations).

						Version 1.0		Version 1.1		
N°	City	Wt E	Wt M	Wt L	IU	Quick response	Reasons	Quick response	Reasons	Comment
1	Wavre	46	71	86	52	Medium term interim use	Nature development	Medium term interim use	Nature development	OK[6]
2	Tournai	48	70	86	61	Orion	Land value/pressure	Orion	Land value/pressure	OK
3	Peronnes-Lez-Binche	49	75	66	63	Medium term interim use	Agricultural development (energy crops)	Medium term interim use	Agricultural development (e.g., energy crops)	OK[7]
4	Loyers	51	67	68	61	Medium term interim use	Agricultural development (energy crops)	Medium term interim use	Agricultural development (e.g., energy crops)	OK[8]
						Urgent solution (mining)	Human health			OK
5	Châtelet	37	57	45	74					
6	Flobecq	40	62	33	86	Medium term interim use	Agricultural development (energy crops)	Medium term interim use	Agricultural development (e.g. energy crops)	OK
						Orion	Valuable content			OK

[6] Probably the best option for the moment as the landfill still produces biogas. The site is located in the Walloon Brabant where the price of the land is high in comparison to other parts of Wallonia. The site is surrounded by commercial areas and is also affected for economic purpose. However, economic areas is not included in the version 1.1. of the Cedalion.

[7] Landfill site surrounded by crops.

[8] Landfill site surrounded by crops. However, there are the presence of pipes to collect biogas, which is not taken into account in the Cedalion.

						Long-term interim use	Agricultural development (ecoforestry)	Long-term interim use	Agricultural development (e.g. agroforestry)	OK
7	Dalhem	68	74	66	55	Urgent solution (mining)	Human health			OK
8	Montigny-le-Tilleul	34	59	70	64					Lack of information regarding the type of waste and its geometry.
9	Liège	53	92	106	42	Orion	Valuable content			OK[9]
10	Ottignies	18	69	83	66	Long-term interim use	Agricultural development (ecoforestry)	Long-term interim use	Agricultural development (e.g. agroforestry)	OK[10]
						Orion	Land value/pressure	Orion	Land value/pressure	OK[10]
						Long-term interim use	Nature development	Long-term interim use	Nature development	OK[10]
11	Kelmis	25	30	51	71	Medium term interim use	Infrastructure development	Medium term interim use	Infrastructure development	OK
						Long-term interim use	Nature development	Long-term interim use	Nature development	OK
12		42	63	60	75	Orion	Land value/pressure	Orion	Land value/pressure	OK[11]

[9] The quick response « Orion – valuable content » was potentially a good answer. The response "Orion – land value/pressure" could also be appropriate, as the site is entirely located in a residential area. However, the removal of the large amount of waste material landfilled on site will be insufficient to ensure the economic viability of the project.
[10] The surface of the landfill site is relatively large (106,830 m^2) and is affected according to the land use planning map in residential area, forest and green space. The three quick responses given by Cedalion directly reflect the land use planning.
[11] The nature development seems more appropriate for the moment as the land use of the site is green space. However, the borders of the landfill site are occupied by houses and it could be potentially expand in the future if the region allows changing land-use affectation of the site.

	Chaudfontaine					Long-term interim use	Nature development	Long-term interim use	Nature development	OK[11]
13	Gemmenich	41	64	41	75	Medium term interim use	Ecological disaster	Medium term interim use	Potential ecological disaster in the future (non-inert waste)	OK
						Long-term interim use	Nature development	Long-term interim use	Nature development	OK
14	Kelmis	49	79	112	25	Orion	Valuable content	Orion	Valuable content	OK[12]
						Medium term interim use	Infrastructure development (solar panels)	Medium term interim use	Infrastructure development (e.g. solar panels)	OK
15	Kelmis	30	52	48	72					Lack of information regarding the type of waste and its geometry.
16	Kelmis	38	58	112	35					Lack of information regarding the type of waste and its geometry[13]

[12] The landfill contains mining waste, which can be potentially valuable.

[13] As there is no input for the type of waste, the depth and the volume of the landfill. Cedalion was not able to provide a clear quick response. If we can have these information, the quick response will probably be "Orion - Land value/pressure" as the site is entirely affected in residential area, surrounded by houses and located in a ZIP 1 region (i.e. region with high land pressure).

17	Kelmis	38	70	78	55	Medium term interim use	Ecological disaster	Medium term interim use	Potential ecological disaster in the future (non-inert waste)	OK
18	Perwez	43	61	52	79	Medium term interim use	Agricultural development (energy crops)	Medium term interim use	Agricultural development (e.g. energy crops)	OK[14]
19	Couvin	44	63	70	75	Long-term interim use	Agricultural development (ecoforestry)	Long-term interim use	Agricultural development (e.g. agroforestry)	OK
						Orion	Land value/pressure	Orion	Land value/pressure	KO[15]
20	Bertrix	42	55	50	73	Long-term interim use	Nature development	Long-term interim use	Nature development	OK[16]
						Urgent solution (mining)	Human health			OK
21	Beauvechain	54	86	117	42	Orion	Land value/pressure	Orion	Land value/pressure	OK[17]
22	Louvain-La-Neuve	24	30	59	64			Long-term interim use	Nature development	KO[18]
23	Tournai	50	60	75	57	Long-term interim use	Nature development	Long-term interim use	Nature development	KO[19]

[14] Landfill site surrounded by crops.
[15] Mostly surrounded by fields and forest. In the north, there is a small rural residential area (see section “step 3” for more explanation).
[16] Landfill site surrounded by forest.
[17] Landfill site located in the Walloon Brabant where the land value is the highest in Wallonia. The site is entirely affected to residential purpose. For this site, we could expect to also have “Orion – valuable content” as quick response as the site is a Bakelite mono landfill.
[18] The site is located in a high-pressure land and is surrounded by houses. We obtained the response Nature development for the following reasons: a small part of the landfill is affected in green space (see section "step 3" for further explanations) and the lack of data (i.e. volume and waste type) making a first approximation of the economic assessment of the project impossible.
[19] The site is located in a high-pressure area, and is surrounded by houses, industrial and economic areas. We obtained the quick response “Nature development” for the following reasons: a small part of the landfill is affected in forest (see section "step 3") and the lack of data (i.e. volume and waste type) making a first approximation of the economic assessment of the project impossible.

24	Morlanwez	32	48	36	70					Lack of information regarding the type of waste and its geometry.
25	Ittre	42	60	88	44					Lack of information regarding the type of waste and its geometry.
26	Huy	24	28	28	72	Long-term interim use	Nature development	Long-term interim use	Nature development	OK
27	Ramillies	27	33	54	72	Medium term interim use	Infrastructure development	Medium term interim use	Infrastructure development	±[20]
28	Hannut	54	37	94	49	Medium term interim use	Agricultural development (ecoforestry)	Long-term interim use	Agricultural development (e.g. agroforestry)	OK
29	Namur	31	45	33	82	Long-term interim use	Nature development	Long-term interim use	Nature development	OK
30	Anderlues	32	45	98	38					Lack of information regarding the volume

[20] "Medium term interim use – Agriculture development (e.g. Energy crops)" seems to be more appropriate as the site is partly affected in agricultural area. We obtained this quick response because a small proportion of the site is allocated for rural residential areas (see section "step 3" for further explanation).

										of landfilled waste[21].
31	Dalhem	42	46	32	86	Long-term interim use	Agricultural development (ecoforestry)	Long-term interim use	Agricultural development (e.g. agroforestry)	OK
32	Jalhay	43	55	55	71					Lack of information regarding the volume of landfilled waste.
33	Liège	36	48	73	73	Medium term interim use	Agricultural development	Medium term interim use	Agricultural development	OK
						Long-term interim use	Nature development	Long-term interim use	Nature development	OK
						Long-term interim use	Agricultural development (ecoforestry)	Long-term interim use	Agricultural development (e.g. agroforestry)	OK
						Medium term interim use	Nature development	Medium term interim use	Nature development	OK
34	Fleurus	42	67	97	51					Lack of information regarding the volume of landfilled waste.

[21] Due to the lack of data, Cedalion was not able to provide a quick response. If the amount of materials landfilled is not so important, the quick response given by Cedalion could be "Orion - Land value/pressure" as the landfill site is entirely affected in residential area and is surrounded by houses.

35	Sambreville	49	76	118	49	Orion	Land value/pressure	Orion	Land value/pressure	OK[22]
36	Auvelais	51	82	88	62	Medium term interim use	Infrastructure development (solar panels)	Medium term interim use	Infrastructure development (e.g. solar panels)	OK[23]
						Orion	Land value/pressure	Orion	Land value/pressure	OK[23]
37	Ciney	41	70	112	40	Medium term interim use	Infrastructure development (solar panels)	Medium term interim use	Infrastructure development (e.g. solar panels)	OK
						Orion	Land value/pressure	Orion	Land value/pressure	±
38	Bastogne	35	46	44	84	Long-term interim use	Agricultural development (ecoforestry)	Long-term interim use	Agricultural development (e.g. agroforestry)	OK
39	Oupeye	18	15	17	93	Long-term interim use development (energy crops)	Nature development	Long-term interim use	Nature development	OK
						Long-term interim use	Agricultural development (ecoforestry)	Long-term interim use	Agricultural development (e.g. agroforestry)	OK
						Medium term interim use	Agricultural development (energy crops)	Medium term interim use	Agricultural development (e.g. energy crops)	OK
40	Hamoir	38	49	47	75	Medium term interim use	Agricultural development (energy crops)	Medium term interim use	Agricultural development (e.g. energy crops)	OK
41	Courcelles	39	58	82	62	Long-term interim use	Nature development	Long-term interim use	Nature development	OK

[22] The landfill site is surrounded by residential and industrial areas.
[23] The landfill site is mostly affected in industrial areas. As the site is also close to a residential area, it is a good choice to develop infrastructure such as solar panels.

42	Tournai	37	61	103	54	Urgent solution (mining)	Human health			OK
43	Tournai	25	31	65	60	Medium term interim use	Infrastructure development	Medium term interim use	Infrastructure development	±
								Long-term interim use	Nature development	OK
44	Lasnes	20	41	86	37	Medium term interim use	Infrastructure development	Medium term interim use	Infrastructure development	OK[24]
45	Chaumont-Gistoux	41	59	87	66	Orion	Land value/pressure	Orion	Land value/pressure	OK[25]
46	Chaumont-Gistoux	40	53	78	63	Long-term interim use	Nature development	Long-term interim use	Nature development	OK
47	Chaumont-Gistoux	58	65	66	63					
48	Gosselies	50	61	87	62	Long-term interim use	Nature development	Long-term interim use	Nature development	OK[26]
49	Dinant	28	49	79	59	Long-term interim use	Nature development	Long-term interim use	Nature development	KO[27]
50	Arlon	31	62	114	35					Lack of information regarding the volume of landfilled waste.

[24] The development of infrastructure could be an option. However, the best quick response according to an expert point of view is “Orion – Land value/pressure”. The landfill site is located in a high-pressure environment where the price of the land is one of the most expensive in the country (see section "step 3" for further explanations).
[25] The landfill site is partly affected in residential areas.
[26] A part of the landfill can be used to develop nature. The northwestern border of the landfill is surrounded by houses and the site can be partially used for residential purpose. However, we obtained the quick response “Nature development” for the following reasons: the landfill is partly affected in green space (see section "step 3" for more explanations) and the lack of data (i.e. waste volume) making a rough economic assessment of the project infeasible.
[27] The landfill site is mostly affected in residential areas. We obtained the response Nature development for the following reasons: the landfill is partly affected in green space (see section "step 3") and the lack of data (i.e. waste volume) making a rough economic assessment of the project infeasible.

51	Fléron	26	34	51	70					Lack of information regarding the volume of landfilled waste.
52	Ottignies	37	59	104	47					Lack of information regarding the volume of landfilled waste.
53	Braine-l'Alleud	28	46	86	55	Medium term interim use	Agricultural development (energy crops)	Medium term interim use	Agricultural development (e.g. energy crops)	OK
54	Kelmis	28	32	33	80	Medium term interim use	Ecological disaster	Medium term interim use	Potential ecological disaster in the future (non-inert waste)	OK[28]
						Long-term interim use	Nature development	Long-term interim use	Nature development	OK
55	Antoing	32	46	64	74	Long-term interim use	Agricultural development (ecoforestry)	Long-term interim use	Agricultural development (e.g. agroforestry)	OK
						Long-term interim use	Nature development	Long-term interim use	Nature development	OK
56	Beaumont	49	64	70	60	Medium term interim use	Agricultural development (energy crops)	Medium term interim use	Agricultural development (e.g. energy crops)	OK

[28] Landfill site located in a groundwater protection zone.

57	Soignies	48	70	86	66	Long-term interim use	Agricultural development (ecoforestry)	Long-term interim use	Agricultural development (e.g. agroforestry)	OK
						Long-term interim use	Nature development	Long-term interim use	Nature development	OK[29]
58	Soignies	29	52	98	49					Lack of information regarding the volume of landfilled waste.
59	Farciennes	32	48	102	41					Lack of information regarding the volume of landfilled waste.
60	Namur	31	49	107	46	Long-term interim use	Nature development	Long-term interim use	Nature development	OK[30]
61	Grace - Hollogne	34	58	91	55					Lack of information regarding the volume of landfilled waste.
62	Jemeppe-Sur-Sambre	44	64	60	79	Long-term interim use	Agricultural development (ecoforestry)	Medium term interim use	Agricultural development (e.g. energy crops)	OK

[29] The landfill site is partly affected in residential areas (43%). We obtained the response "Nature development" for the following reasons: the landfill is partly affected in green space (34 % - see section "step 3" for further explanations) and the lack of data (i.e. waste volume) making the first economic assessment of the project infeasible.
[30] The landfill site is partly affected in industrial areas (70%). We obtained the response "Nature development" for the following reasons: the landfill is partly affected in green space (25 % - see section "step 3" for further explanations) and the lack of data (i.e. waste volume) making the first economic assessment of the project infeasible.

						Long-term interim use	Nature development	Long-term interim use	Nature development	OK
						Medium term interim use	Agricultural development (energy crops)	Long-term interim use	Agricultural development (e.g. agroforestry)	
63	Boussu	52	77	82	62	Urgent solution (mining)	Human health[31]			OK

Table 2 - Results of the testing of Cedalion tool for selected landfill sites from Walsols.

[31] Related to the presence of a groundwater reservoir on site. However, Cedalion does not take into account the degree of water contamination and/or the hydrogeology of the site.

For two RAWFILL pilot sites out of seven (Meerhout and Emerson's green), Cedalion was not able to provide a quick response. A similar proportion was observed for the landfill sites selected from Walsols where Cedalion could not give a quick response for 28 % of the landfill sites. The main reasons are:

- The lack of information about the volume of waste deposits and its composition;
- A similar scoring for WtM, WtL, WtE, IU (and therefore no clear answer for the future of the landfill site).

In the past, landfills were considered as black box where only the production and the composition of biogas and leachates were analysed and studied. Information about the type of waste deposits are either missing in Walsols or the waste descriptions are too rudimentary. Therefore, further investigations (e.g. geophysical survey, waste sampling) are required on these sites to fully complete the ELIF and the Cedalion in the future. The second reason is that the Cedalion was designed to provide quick responses only when it is appropriate. If a clear quick response cannot be given, the Cedalion tool will provide no response at all. However, even if no quick response was provided by the Cedalion, the user still has the possibility to run the Orion tool (DST 2).

The number of quick responses obtained for a landfill site varies between 0 and 5. On average, most of the sites only obtained one quick response. For 11 % of the landfill sites, the quick responses obtained were not matching the expert advice. This is mostly related to the simplicity of the tool and its limits (see section 3 for further information).

Figure 6 shows the distribution of the quick responses obtained during the testing phase (Cedalion 1.1.). The long-term interim use – Nature development is the most popular quick response obtained. Regarding the revalorization of the landfill into WtM and WtL, the reclaiming of the land is a better option for most of the landfill than the waste revalorization : 10 landfills got the quick response "Orion – Land value/pressure" whereas only two landfill sites seems suitable to start a landfill mining project only based on waste revalorization (i.e. "Orion – Valuable content"). However, these results should be balanced. Only the main categories of waste material are listed in the Cedalion. Landfills having specific valuable waste are categorized into industrial or inert whereas in reality the waste material contained in the landfill is more valuable. Moreover, the proportion between the different waste materials present within the landfill is not included. The Orion decision support tool was developed to refine the responses given by the Cedalion.

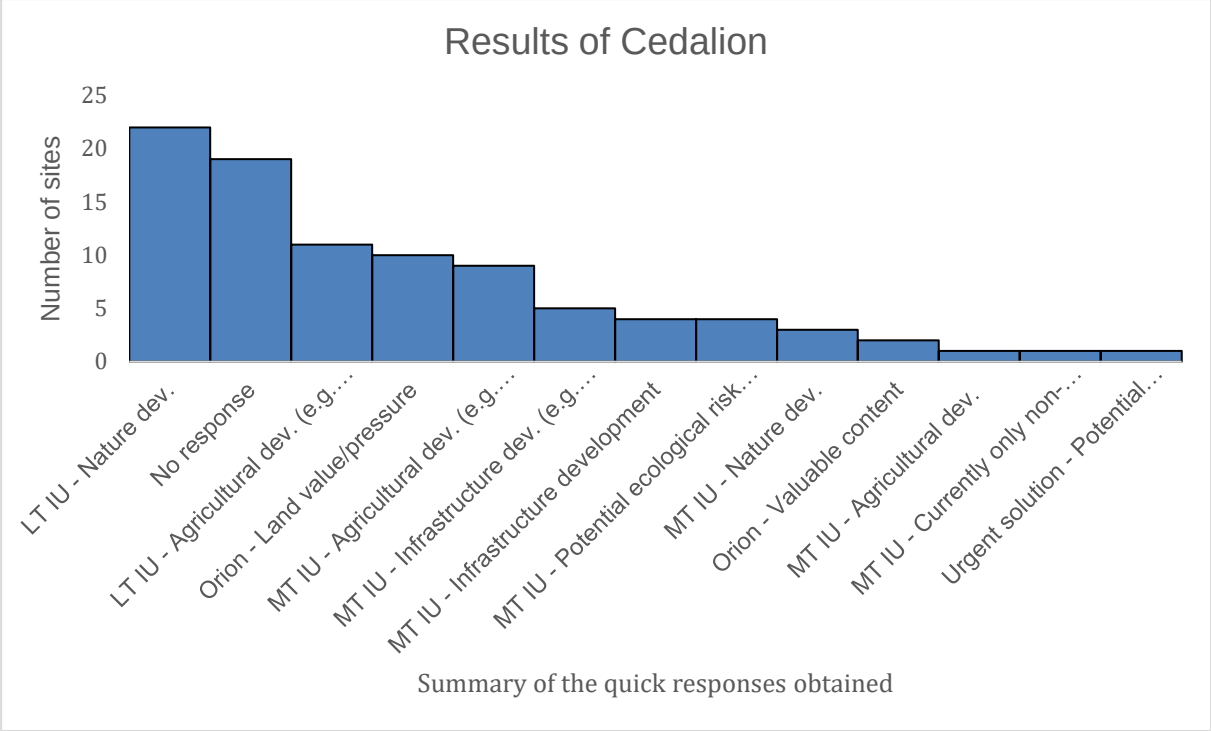

Figure 6 - Distribution of the quick responses obtained during the testing phase of Cedalion v1.1.

Step 3 - Reporting to OVAM to fine-tune the Cedalion.

After each testing phase, a report was sent to OVAM, which fine-tuned the tool and corrected the bugs. The testing phase showed that the quick responses obtained were generally coherent with the reality and match with the expert advice. However, the tool also has its limits. The Cedalion tool was designed to be easy to use and could be used by everybody (e.g., municipalities, private company, etc.) - even people with limited knowledge in landfill management. In order to keep the tool simple, only a few indicators were selected from the ELIF and are required to run it. This limited number of indicators is the reason why in specific cases, the Cedalion tool showed its limits. For instance, the percentage of land affected to different land use is not taken into account. If a landfill has only 5% of its surface area dedicated to residential areas and 95% in agriculture, it will appear in Cedalion as the landfill is affected to residential and agricultural areas without mentioning the percentage. In that example, Cedalion will provide the quick answer ”Orion – land value/pressure” as quick response which is not reflecting the reality of the case. The contrary is also possible, if a landfill has 95% of its surface area affected into residential areas and 5% dedicated to Nature area, the nature area will always win and the user will obtain “long-term interim use – Nature development” as a quick response. Moreover, the simplicity of the Cedalion tool only lists the most common categories of waste materials found in landfills without taking into account the proportion of waste deposits contained within the landfill.

The value of the land as well as the land pressure are not taking into account in the scoring of the Cedalion. The quick answer “Orion – land value/pressure” are only based on the presence of a residential area/industrial area. For Stockley Park, the quick response given by Cedalion is “Medium term interim use - Infrastructure development (e.g. solar panels)” despite the high score obtained for WtL (125). The explanation behind the response is that for most of the landfill sites, removal of large volume of waste materials is quite expensive and is not economically viable. Therefore, medium interim use is generally the most suitable option. However, some landfill sites like Stockley Park are located in areas where the land value is relatively high and selling the reclaimed land with a

redevelopment project is sufficient to guarantee the financial balance of the landfill mining project. For instance, Stockley Park is located in the suburbs of London, close to Heathrow airport where the land price is relatively high. For this site, the most appropriate quick response should be "Orion – land value/pressure". As the land value is not included as indicators in Cedalion, we will always obtain a biased quick response for these kinds of landfills. In order to not make the tool more complex, it was decided not to include "land price" as an indicator for Cedalion.

The user should keep in mind that the Cedalion tool is a basic tool providing a first selection of promising sites. The user should remain critical when he obtains a quick response and should verify it by using the Orion - DST 2 in order to ensure the reliability of the given quick responses.

3. Decision Support Tool level 2 - Orion

Based on the results of the Cedalion tool, landfill sites which have obtained as quick responses "Orion – land value/pressure" and "Orion – valuable content" as well as a few landfill sites which have obtained no quick answer were selected to test the three different versions of the Orion tool. Based on this testing, the logic tree behind the Orion tool was modified. In the first version of the Orion tool, the testing highlighted a lack of coherence between the results obtained in the Cedalion tool and the Orion tool. This major issue was finally solved in the version 1.2 of the Orion tool. In order to make the Orion tool more user-friendly, the dashboard and the roadmap version 1.3. were transformed into a web-based application. The interim use option was also developed by adding a new IU module in the version 1.3. of the tool. In this section, we present in detail the results obtained for three landfills from the OVAM database: landfill n°1007 located in Vilvoorde, landfill n°2211 located in Ghent and landfill n°3301 located in Schoten. At the end of this section, the results obtained for the RAWFILL Pilot sites are discussed.

3.1. Landfill n°1007 – Vilvoorde

3.1.1. Results in Cedalion

In Cedalion, landfill n°1007 received the quick response "Orion" because of high land value and pressure. When looking at the individual ranking scores for the valorisation scenario's, there seems to be a high potential for the WtL scenario compared to the average score for that scenario (Fig. 7). Therefore, it can be interesting to use the Orion tool in order to evaluate if a business case would be feasible for this landfill.

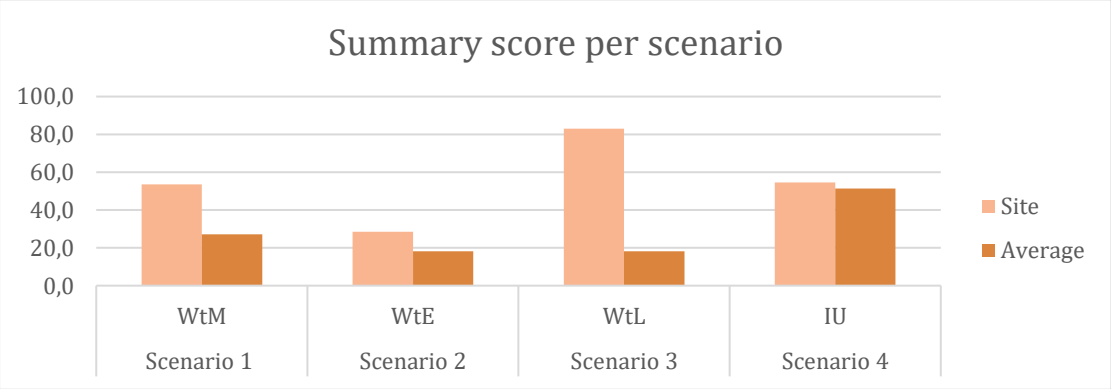

Figure 7 – Summary scores per scenario for landfill n°1007 located in Vilvoorde, Belgium.

3.1.2. Description of the landfill

The landfill site is located in a larger industrial area east of the train station of the city of Vilvoorde (Flanders, Belgium). The site has a total area of approximately 30,000 m². The site is indicated in blue on the aerial photograph below (Fig. 8). The current urban planning has designated the site for mixed commercial/industrial activities. Currently the site comprises vacant land, two office buildings, roads and a parking. The landfill contains household waste (soil, wood, bricks, …) and industrial waste and is covered by approximately 1,5 m of clean top soil. The landfill is 4 m thick (1,5 – 5,5 m below the current ground level). Its volume was estimated to 180,000 m³ for approximately 310,000 tonnes of waste.

Regarding the history of the site, before the 1950s, the site was agricultural land. In 1951, the first landfill activities started at the east of the site. Officially, in 1954, a permit was provided by the municipality to use the site as a horse cemetery. In the following years, the site was used for the disposal of household waste.

Figure 8 - Aerial photograph 2020: Location of landfill 1007, Vilvoorde, Flanders, Belgium.

3.1.3. Results of Orion

The results of the Orion roadmap can be visualized in Appendix 1. For this site, the endpoint "develop remedial action plan" was reached. The reason behind this response is that this landfill is a mixed landfill, containing a mix of household and municipal waste. Hence, the landfill cannot consider as a mono landfill. According to the soil investigation study performed on site in 2017, some risks for human health were identified due to the presence of heavy metals, benzene and mineral oil in the waste deposits. Currently, these risks are under controlled but when redevelopment project would take place, action should be taken in order to reduce significantly these risks.

Therefore, Orion results suggested using a risk assessment model in order to define if remedial actions are necessary or not. For this site, a risk assessment was already done by means of a descriptive soil investigation performed by soil remediation experts. From this investigation, the following was concluded:

"Remediation is necessary because there is a potential risk for future use for humans due to potential vapour inhalation from the volatile (BTEX and VOCl) contaminations present in the landfill. This risk is not present for the current site use as was demonstrated by air measurements. Soil vapour measurements show strong variations in the measured methane concentrations. Currently no landfill gas or leachate is being captured. Pockets of pure product (LNAPL) are present in the landfill. The filled material is directly in contact with the groundwater. The groundwater of the subject site and the adjacent former landfills is contaminated."

3.1.4. Conclusion

At this moment, the development of a remedial action plan is necessary, as prevention of pollution and ecological and human risks remains the essential goal.

3.2. Landfill n°2211 – Ghent

3.2.1. Results in Cedalion

In Cedalion tool, landfill n°2211 receives no quick response. However, when looking at the individual ranking scores for the valorisation scenario's, there seems to be a high potential for the WtL scenario compared to the average score for that scenario (**Fig. 9**). Therefore, it can be interesting to use the Orion tool in order to evaluate if a business case would be feasible for this landfill.

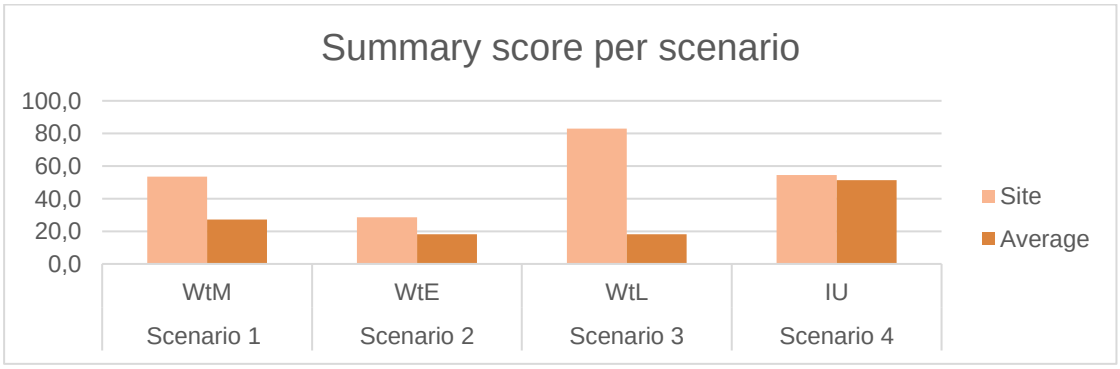

Figure 9 - Summary scores per scenario for landfill n°2211, Ghent, Belgium.

3.2.2. Description of the landfill

The landfill site is located at the north of the city centre of Ghent, Flanders, Belgium. To be more precise, it is located in the most southern part of the Ghent harbour between the Wiedauwkaai and the Buitensingel. The area was a marsh land before the extension of the Ghent harbour, in the second half of the 20th century, took place. The marshes ("Meersen") were filled with all types of material to create dry land to extend the city and its harbour activities.

In the last decade, the site has been redeveloped. Along the railway, a new road has been constructed to allow redevelopment of the western part of the "Wondelgemse Meersen". In the central part, a Forensic Psychiatric Centre has been built.

According to the urban planning regulations, parts of the area have been designated as industrial land (northern part of area A and area D in **Fig. 10**) and other parts as land for community services (southern part of area A, area B and area C in **Fig. 10**).

In the beginning of the 1960s, the first landfill activities started at the subject site. These were localised in the western part of area A. North of the site landfilling was already fully ongoing. Most likely the

landfilling that was started on the adjacent northern site was extended to the south on the subject site. Before the site was being landfilled was used as agricultural land. In 1973, a first official permit was granted by the city of Ghent for the deposition of liquid faeces in earthen basins for a period of 10 years. These activities took place in the central area of the site. Based on field observations not only faeces were deposited but also household waste, ashes, slag and potentially some industrial waste were dumped also. These activities ware most likely terminated in the beginning of the 1980s. The dumped material was covered with a thin layer of soil (10 to 20 cm thick). During the 1990s the most southern part of the site was used to dump inert demolition waste.

Based on the historical dumped material the following areas are defined:

- Area A: former faeces, demolition waste and household waste landfill (1960s-1980s)
- Area B: demolition waste and soil landfill (1960s-1980s)
- Area C: demolition waste (1980s-2000s)
- Area D: demolition waste, soil and household waste landfill (1970s-1980s)

Figure 10 - Aerial photograph 2020 with the location of the Landfill n°2211 and its geographical division based on type of waste deposits.

Household waste landfill (Area A)

- 68.000 m²
- Average 2,5 m thick (up to 3 m thick)
- 170.000 m³
- 300.000 ton
- Household waste (unknown composition), soil and demolition waste

Area A of the site has been redeveloped as a Forensic Psychiatric Centre including access roads. No additional measures have been taken with respect of the waste material present. The new centre was building on top of the waste material present.

3.2.3. Results of Orion

Although there is already a redevelopment in place of the landfill, the Orion tool was used to see what would be the output if the site was not redeveloped, yet. The results of the Orion roadmap are visualized in **Appendix 2**.

In this section, the roadmap taken for the landfill n°2211 is presented into details. The landfill contains household waste (with an unknown composition) and demolition waste, so it is not a mono landfill. There are no indications about the presence of hazardous waste. The landfill has a volume of 170,000 m³, so bigger than 20,000 m³. The ratio between the total volume and the surface of 68,000 m² is smaller than 4. There is no waste stored above ground level so the ratio between the total volume and the above-ground volume is not smaller than 1,25. There is no information available on the complexity of a possible excavation. There is only some volume of the landfill present in the unsaturated zone of the groundwater (64%), hence, the ratio between the volume in the unsaturated zone and the volume in the saturated zone is bigger than 5. As the site is already developed, the distance to infrastructure is 0 in reality. However, because the landfill is being considered without redevelopment, a distance of more than 10 m is indicated. At this point, Orion indicates that an excavation would be feasible and that ONTOL should be used in a following step.

The ONTOL results for area A of the landfill are visualized in **Appendix 3**. For this example, the default values were directly replaced with the site-specific values. When using the specific values, the specific Net Present Value for the project is estimated to be -16,6 euro/tonne of waste. When completing the formula in the roadmap: NPV > -20,000 € / total volume, this results in a value of -0,067 for a total volume of 300,000 tonnes of waste. The loss calculated by ONTOL is way bigger than the loss that is accepted by the Orion tool. Hence, it is not feasible to set up a business case for a landfill mining/rehabilitation project. Instead, an interim use could be installed. .

3.2.4. Conclusion

Despite the high score for the WtL scenario in Cedalion tool, it does not seem feasible to set up a landfill mining project according to the Orion tool. This can be explained by the simplicity of the Cedalion tool which does not take into account the land price directly, among others. In this case, the limitation of Cedalion tool is reached. This is why, it is important to develop a business case before starting a landfill project. Here, Orion tool advised to develop an interim use on site instead of setting up a landfill mining project. This is what happened in reality: the site has been redeveloped as a Forensic Psychiatric Centre, built on top of the waste material that is still present above.

3.3. Landfill n°3301 – Schoten

3.3.1. Results in Cedalion

In Cedalion, landfill n°3301 received the quick response 'Orion' because of a high land value and/or pressure. When looking at the individual ranking scores for the valorisation scenario's, there seems to be a high potential for the WtL scenario compared to the average score for that scenario (Fig. 11). Also the score for the WtM scenario is relatively high compared to the average value. Therefore, it can be interesting to use the Orion tool in order to evaluate if a business case would be feasible for this landfill.

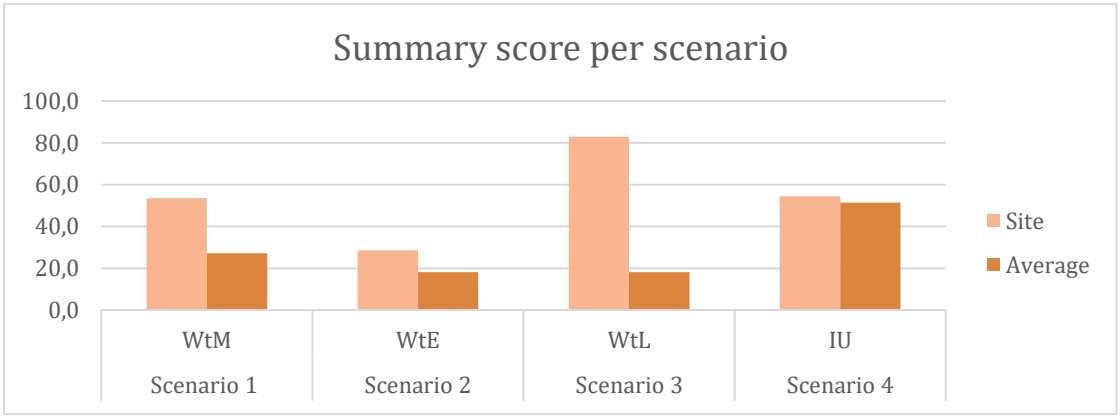

Figure 11 - Summary scores per scenario for landfill n°3301, Schoten, Belgium.

3.3.2. Description of the landfill

The landfill is located along the E19, a highway in Flanders, Belgium. The landfill acts as a noise cancelling barrier to break the noise that comes from the highway. This landfill mainly consists of demolition waste mixed with soil. Its superficies is 3,010 m² and its volume was estimated to 10,000 m³ which corresponds to a weight of approximately 19,000 tonnes. The landfill activities started around 1995. Due to the location of the landfill between the highway and a residential area (Fig. 12), the main driver for a landfill mining project would be nature development instead of the noise cancelling barrier of waste materials.

Figure 12 - Aerial photograph 2020 showing the location of the Landfill n°3301.

3.3.3. Results of Orion

The roadmap is presented in **Appendix 4**. The landfill contains demolition waste. It is not sure whether this demolition waste consists of homogenous or heterogenous materials. Therefore, the 'I don't know' option was chosen for the first question 'Is your landfill a mono landfill?'. Following the answer "I don't know", Orion tool asked a series of questions to determine if the landfill can be considered as monolandfill. Demolition waste was not present in the list of examples of monolandfills provided by Orion tool. Moreover, there was no Resource Distribution Model available for this landfill site. Lastly, the history of the landfill is not linked to one type of production. Based on these answers to the questions, Orion assumed that landfill n°3301 is not a mono landfill, but a mixed landfill.

Based on the available information, there are no indications regarding the presence of hazardous waste. The volume of the landfill (10,000 m³) is smaller than the suggested threshold of 20 000 m³. The majority of the waste volume is present above ground level (**Fig. 13**). Therefore the ratio between the total volume and the above-ground volume is smaller than 1,25. Based on these characteristics, Orion suggested that an excavation would be feasible.

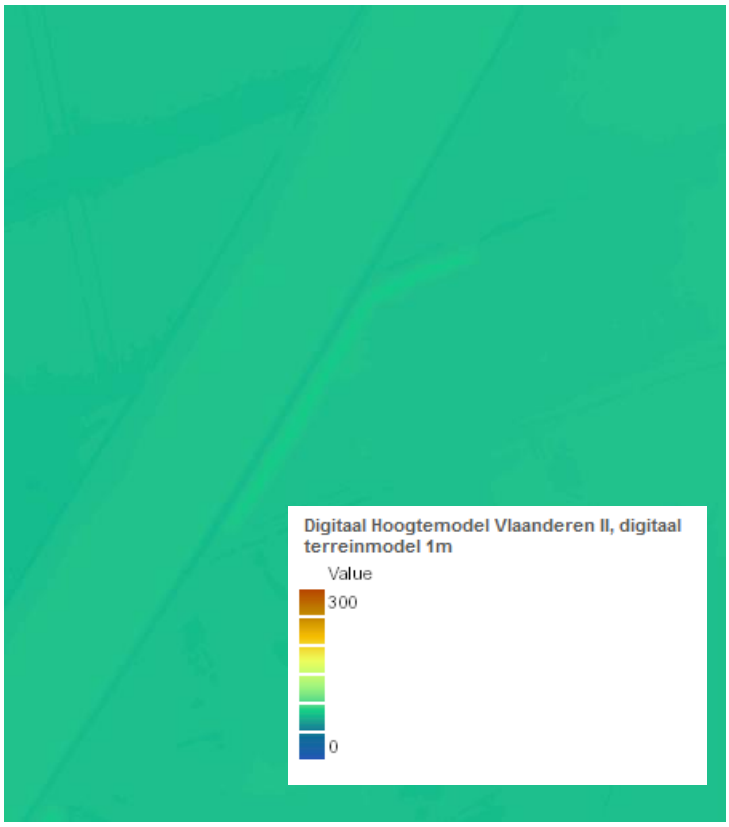

Figure 13 - Digital elevation model for landfill n°3301.

The following step was to use the ONTOL model in order to evaluate if a business case would be feasible (see **Appendix 5**). For this example, the default values were directly replaced with the site-specific values. When using the specific values, the specific Net Present Value for the project is estimated to be 14,8 €/tonnes of waste. This means that mining the waste within the landfill, would have a positive economic value. Hence, the NPV was positive and Orion suggested going further and develop a business case (see Deliverable ***WP T3.2.2. Business cases*** for more information regarding the creation of a business case).

3.3.4. Conclusion

The Cedalion tool as well as the Orion tool detected this landfill as a high potential for the waste-to-land scenario. The waste is now used as a noise cancelling barrier, but there seem to be more sustainable ways to cancel the noise coming from the highway. Developing natural green barrier would be a feasible business case to substitute the barrier that now consists of waste. Parts of the waste and soil present in the landfill can be reused.

3.4. RAWFILL Pilot sites

Once the final version of the DST 2 – Orion has been delivered, it was applied on seven of the RAWFILL pilot sites. The results are summarized in the **Table 3**.

	Cedalion v 1.3						Orion v 1.3
Site	WtE	WtM	WtL	IU	Quick response	Reasons	
Onoz	44	64	60	79	**Orion**	**Land value/pressure**	**Develop Enhanced Landfill Mining (ELFM) project**
					Long-term interim use	Nature development	
					Long-term interim use	Agricultural development (e.g. agroforestry)	
					Long-term interim use	Nature development and conservation	
Les Champs Jouault	64	70	54	75	**Medium term interim use**	Currently only non-recyclable goods	**Set up interim use**
					Medium term interim use	Infrastructure development (e.g. solar panels)	
La Samaritaine (Lingreville)	45	76	90	70	Medium term interim use	Potential ecological risk in the future (non-inert waste)	**Develop remedial action plan**
					Urgent solution	**Potential ecological risk in the future (non-inert waste)**	
					Long-term interim use	Nature development	
					Medium term interim use	Nature development	
					Orion	Valuable content	
					Long-term interim use	Nature development and conservation	
Leppe	61	82	95	54	**Medium term interim use**	Infrastructure development (e.g. solar panels)	**Set up interim use**
Meerhout	61	64	70	60			**Set up interim use**

Emerson's green	34	56	93	47.5			**Develop business case**
Stockley Park	43	71	125	35	Medium term interim use	Infrastructure development (e.g. solar panels)	**Develop business case**

Table 3 – Comparison between the results of the Cedalion and Orion tools for seven RAWFILL pilot sites.

DST 2 – Orion identified the three pilot sites which are a-priori the most suitable to launch a landfill mining project : the landfill of Onoz, Emerson's green and Stockley Park. The authorization to start a landfill mining project at Onoz landfill site was given in Spring 2021. A private company will start soon to recover the valuable materials. The expected duration of the ELFM project is estimated to 13 years. Regarding Emerson's green landfill, landfill mining operations have started in 2019 to reclaim the land to build residential houses. For Stockley Park landfill, the project preparation is ongoing. Private investors are interested in land recovery as the site is close to London and Heathrow airport.
DST 2 – Orion highlighted the ecological risks related to the presence of La Samaritaine Landfill (Lingreville). The landfill site was located along the coast and the edge of the landfill was regularly eroded by the waves during storms. Urgent remediation actions were taken in 2017-2018 to excavate the landfilled waste materials in order to secure the landfill site.
Concerning the interim use options, DST 2 – Orion identified three potential RAWFILL pilot sites : Leppe, Meerhout and Les Champs Jouault. This is mainly due to the presence of large volume of non-valuable and non-hazardous waste materials which would make impossible the economic viability of a landfill mining project. Overall, the responses obtained with the DST 2 – Orion for the RAWFILL pilot sites are coherent with an expert judgment.

Conclusion

The performance report for DST 1 – Cedalion and DST 2 – Orion showed good results for both tools. However, the performance report highlighted the limits of DST 1 - Cedalion. These limits are related to the simplicity of the tool. The spatial distribution of different land uses of the site as well as the proportion of different waste materials are not included in this tool which can lead, in rare cases, to an erroneous answer. Therefore, the user should keep in mind that the Cedalion tool is a basic tool providing a first selection of promising sites. The user should remain critical when a quick response is obtained and should verify it by using the DST 2 - Orion in order to ensure the reliability of the given quick responses. The testing of the DST 2 – Orion showed that the tool usually provides an answer that is coherent with an expert judgment and can correctly orientate the user towards different open-access tools in order to refine future redevelopment project(s) on the landfill.

Contact

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Appendix 1

Orion results for landfill n°1007

Submit date: Jun 9, 2021 Response label: 1007

Results Cedalion

Select a landfill with high scores in Cedalion.

Fill in the name or reference of your chosen landfill: 1007

<< Back to Orion Dashboard

Is your landfill a mono landfill?

(○) Yes (●) No (○) I don't know

Does your landfill contain hazardous waste?

(●) Yes (○) No

Use Risk Assessment Model

Are remedial actions necessary?

(●) Yes (○) No

Your stop:

Develop remedial action plan

If you would like to receive the results to your email, please enter it here: cuinera.isenborghs@ovam.be

CONCEPTUAL SITE MODEL

Appendix 2

Orion results for landfill n°2211

Submit date: Jun 8, 2021 Response label: 2211

Results Cedalion

Select a landfill with high scores in Cedalion.

Fill in the name or reference of your chosen landfill: 2211

<< Back to Orion Dashboard

Is your landfill a mono landfill?

○ Yes ◉ No ○ I don't know

Does your landfill contain hazardous waste?

○ Yes ◉ No

V < 20 000 m^3?

○ Yes ◉ No

V/S < 4?

◉ Yes ○ No

V/Va < 1,25?

○ Yes ◉ No

Complex excavation?

○ Yes ○ No ◉ I don't know

Vu/Vs > 5?

◉ Yes ○ No

Distance to infrastructure > 10m?

(•) Yes ( ) No

Excavation feasible

Use ONTOL default values

NPV > -200 000/V?

( ) Yes (•) No

Detailed investigation with ONTOL: replace default values

NPV > -20 000/V?

( ) Yes (•) No

Your stop:

Set up interim use

If you would like to receive the results to your email, please enter it here: cuinera.isenborghs@ovam.be

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CONCEPTUAL SITE MODEL

Appendix 3

ONTOL results for landfill n°2211

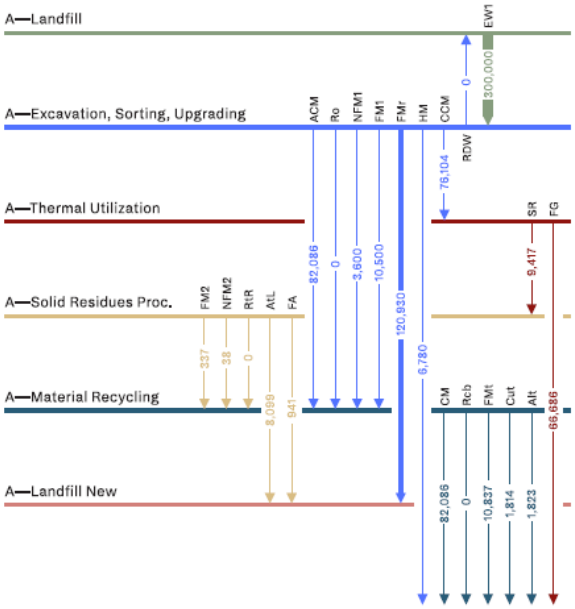
Online Tool for the Economic and Ecologic Evaluation of Landfill Mining

Project name: **Gent - Area A landfill**

Analysis type: Material flows, climate impact and economics of LFM project

Date of export: 12.06.2020

1-Results on the physical flows



ID	Description	Flow Mg/yr	Flow Mg
Excavation, Sorting and Upgrading			
EW1	Excavated waste	100,000	300,000
RDW	Residues (internally re-deposited) (total)	0	0
FMr	Residues (to external landfill) (total)	40,310	120,930
FM1	Ferrous metals (total)	3,500	10,500
NFM1	Non-ferrous metals (total)	1,200	3,600
Ro	Plastics to recycling (total)	0	0
HM	Hazardous materials (total)	2,260	6,780
ACM	Aggregates (total)	27,362	82,086
Waste Incineration			
CCM	Combustible materials (total)	25,368	76,104
FG	Off gas	22,228	66,686
SR	Solid residues (bottom ash, fly ash and APC residues)	3,139	9,417
AtL	Bottom ash to landfill	2,699	8,099
FA	Fly ash and APC residues	313	941
FM2	Fe scrap recovered	112	337
NFM2	NFe scrap recovered	12	38
RtR	Aggregates (derived from bottom ash) to recycling	0	0
Material Recycling			
FMt	Ferrous metals (total)	3,612	10,837
Cut	Copper (total)	604	1,814
Alt	Aluminium (total)	607	1,823
CM	Construction materials (aggregates)	27,362	82,086
Rcb	Plastics to recycling (total)	0	0

2-Results on climate impact

	Burdens			Savings		
Processes	Direct emissions [Mg CO_2 eq]	Indirect emissions [Mg CO_2 eq]	Avoided savings [Mg CO_2 eq]	Savings [Mg CO_2 eq]	Avoided direct emissions [Mg CO_2 eq]	Avoided indirect emissions [Mg CO_2 eq]
Reference Case	0	0	0	0	76,252	0
Emissions during LFM	3,268	0	0	0	0	0
Excavation, Sorting, Upgrading	0	2,568	0	0	0	0
Thermal utilization	30,895	357	0	38,405	0	0
Solid Residues Processing	0	51	0	0	0	0
Material Recycling	0	0	0	33,371	0	0
Landfill New	6,587	1,013	0	0	0	0
Re-deposited waste	0	0	0	0	0	0
Transport	0	3,746	0	0	0	0
Total	**40,750**	**7,735**	**0**	**71,776**	**76,252**	**0**

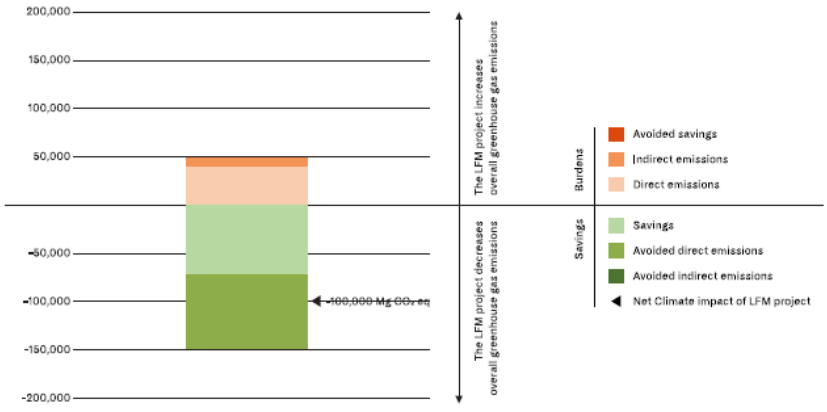
Direct emissions include greenouse gas emissions GHG that result from the waste itself (e.g. landfill gas). **Indirect emissions** include GHG emissions that result from the energy supply of different processes (e.g. energy demand for leachate treatment). **Avoided savings** include basically GHG emissions that would have been avoided in the reference case (e.g. substituting fossil fuels by utilizing landfill gas). **Savings** include avoided GHG emissins by substituting fossil fuel or primary raw materials. **Avoided direct emissions** include direct emissions that are avoided by the LFM project. **Avoided indirect emissions** include indirect emissions that are avoided by the LFM project.

Final results

Description	Value	Unit
Total burden	48,500	Mg CO_2 eq
Total saving	148,000	Mg CO_2 eq
Net climate impact of LFM project	-99,500	Mg CO_2 eq
Specific net climate impact of LFM project	-0.332	Mg CO_2/Mg excavated

A negative net climate impact indicates savings of greenhouse gas emissions by the LFM project.

Global Warming [Mg CO_2 eq]



	[Mg CO_2 eq]
Direct emissions	40,750
Indirect emissions	7,735
Avoided savings	0
Savings	-71,776
Avoided direct emissions	-76,252
Avoided indirect emissions	0

Calculation of the annual cash flows [Euro]

Year	Costs	Revenues	Avoided Revenues	Avoided Costs
0	8,950,000	3,170,000	0	20,400
1	8,890,000	3,170,000	0	20,400
2	8,970,000	11,900,000	0	20,400

3-Results on the economy of LFM project

Initial costs

Description	Euro
Intermediate Use	0
Planning and Permits	65,000
Purchase of site & installations	0
Excavation, Sorting, Upgrading (investment costs)	0

Annual costs during project

Description	Euro/yr
Intermediate use	0
Landfill management	0
Excavation, Sorting, Upgrading (operational costs)	3,850,000
Thermal utilization	2,540,000
Solid residues processing	0
Disposal costs (external)	1,770,000
Transport costs	724,000

Annual costs after the end of the project

Description	Euro/yr
Aftercare costs of re-deposition landfill	0

One-time costs at the end of the project

Description	Euro
Final cover of re-deposition landfill	0
Landscaping, env. supervision & overhead	80,000
End of life costs of intermediate use	0

Annual revenues during project

Description	Euro/yr
Intermediate use	0
Revenues from landfill itself during time of intermediate use	0
Valorization of el & heat from LFG	0
Valorization of el & heat from WtE	0
Valorization of materials	3,170,000

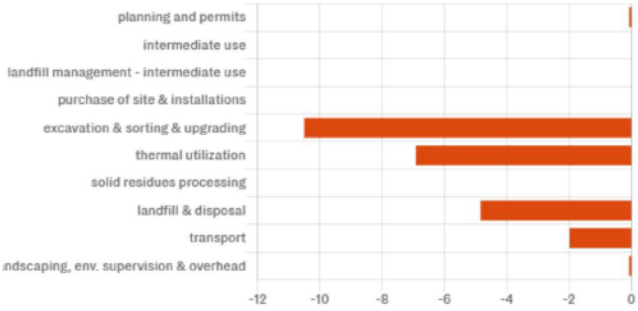
Revenues at the end of the project

Description	Euro
Valorization of recovered land	8,770,000
Valorization of recovered landfill space	0
Valorization of used machinery	0

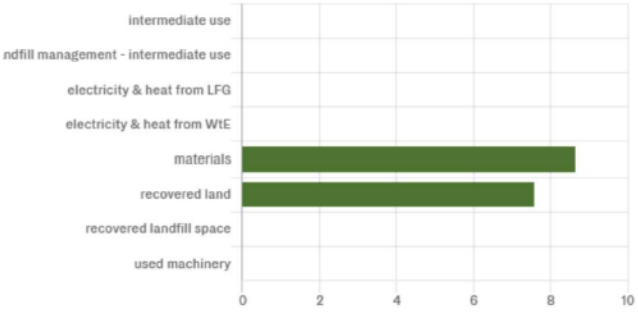
Final results

Description	Value	Unit
Net present value of costs	**-24.3**	**Mio Euro**
planning and permits	-0.065	Mio Euro
intermediate use	0.0	Mio Euro
landfill management - intermediate use	0.0	Mio Euro
purchase of site & installations	0.0	Mio Euro
excavation & sorting & upgrading	-10.5	Mio Euro
thermal utilization	-6.91	Mio Euro
solid residues processing	0.0	Mio Euro
landfill & disposal	-4.83	Mio Euro
transport	-1.97	Mio Euro
landscaping, env. supervision & overhead	-0.0658	Mio Euro
Net present value of avoided revenues	**0.0**	**Mio Euro**
Net present value of revenues	**16.2**	**Mio Euro**
intermediate use	0.0	Mio Euro
landfill management - intermediate use	0.0	Mio Euro
electricity & heat from LFG	0.0	Mio Euro
electricity & heat from WtE	0.0	Mio Euro
materials	8.64	Mio Euro
recovered land	7.58	Mio Euro
recovered landfill space	0.0	Mio Euro
used machinery	0.0	Mio Euro
Net present value of avoided costs	**0.0**	**Mio Euro**
Total net present value of the project (TNPV)	**-8.11**	**Mio Euro**
Specific net present value (SNPV)	**-27.0**	**Euro/Mg**

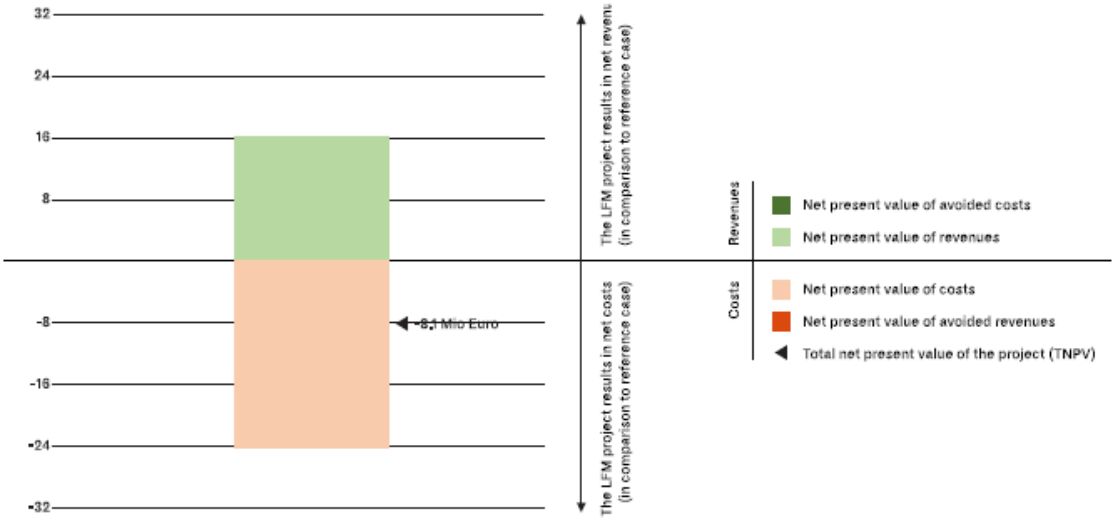
Net present value of costs [Mio Euro]



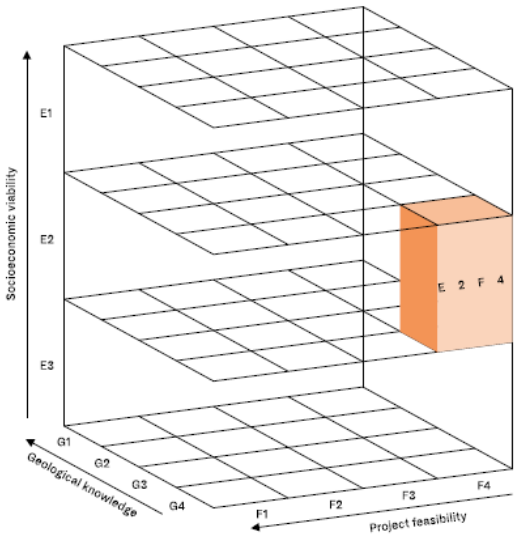
Net present value of revenues [Mio Euro]



Net present value



4-Results on resource classification of LFM project



- **Socioeconomic viability**

	SNPV (Specific net present value) -27,04 Euro/Mg		SNCI (Specific net climate impact) -0,33 kg CO_2 eq/Mg	
	>=	<	>=	<
E1	0	∞	-	-
E2	-15	0	-	-
	-30	-15	-∞	0
E3			0	∞
	-∞	-30	-	-

- **Project feasibility**

	Project status
F1	approved
F2	approval phase
F3	approval not started
F4	pre-exploration phase

- **Geological knowledge**

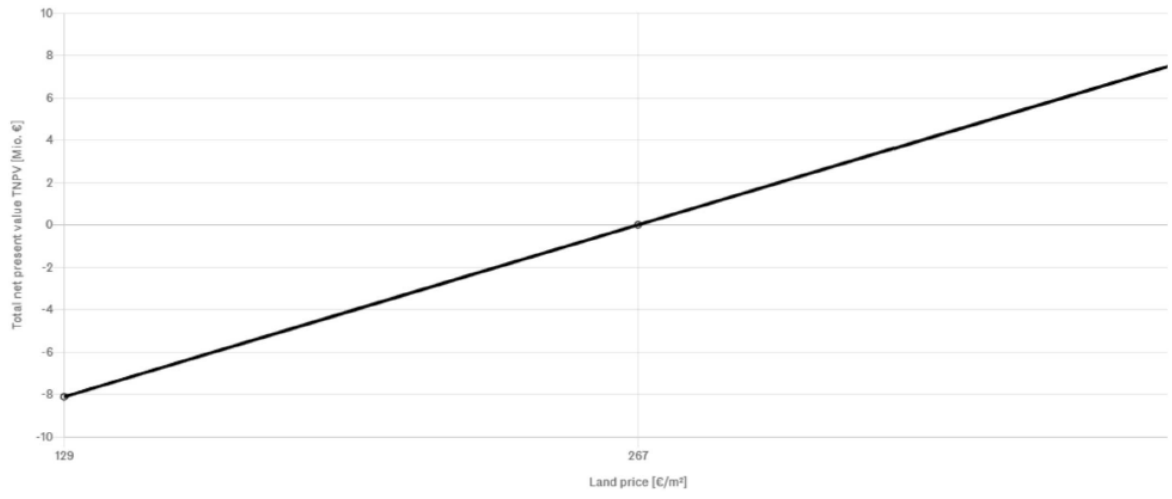
	Waste composition data
G1	very good
G2	medium
G3	poor
G4	unqualified estimate

Calculation of cut-off values

Cut off values for different parameters

Description	Cut off value	Current value	Required increase/ allowed decrease(*)
Price of regained land	267 Euro/m²	129 Euro/m²	207 %
Price of regained landfill space	0 Euro/Mg	0 Euro/Mg	
Price of valorized metals	1,250 Euro/Mg	672 Euro/Mg	188 %
Costs for thermal treatment	-17 Euro/Mg	120 Euro/Mg	
Costs for disposal of residues	-20 Euro/Mg	30 Euro/Mg	

(*) required increase in case that TNPV<0, allowed decrease in case that the TNPV>0



Applied Changes

The following input and output values were changed because of conditional rules:

Reason	Changes
Landfill gas collection in place (ag1) is no	Landfill gas collection rate (ag2) was set to 0 m³/m³ Collection rate of LFG (r3) was set to 0 m³/m³ Costs for LFG management (rec3) was set to 0 Euro/yr
Is excavated material re-deposited at the site (ap4) is no	Landfill gas potential of the re-deposited waste (ag11) was set to 0 m³/Mg
Leachate collection in place (a11) is no	Leachate treatment costs (re1) was set to 0 Euro/m³ of leachate Leachate treatment costs (ae3) was set to 0 Euro/m³ of leachate Leachate generation before final cover installation (ac3) was set to 0 m³/year Leachate generation after final cover installation (ac4) was set to 0 m³/year
Landfill gas collection in place (ag1) is no **AND** Leachate collection in place (a11) is no	Gas collection and treatment costs (ae4) was set to 0 Euro/m² of landfill area Price of electricity (consumed) (ae8) was set to 0 Euro/GJ Electricity demand for gas and leachate treatment (landfill management) (a22) was set to 0 MJ/Mg.yr Climate impact of electricity use in reference case (rgc2) was set to 0 kg CO_2 eq
Intermediate use of landfill before mining project (ap9) is no	Investment costs of intermediate use (ge9) was set to 0 Euro Annual costs of intermediate use (ge10) was set to 0 Euro/year Annual revenues of intermediate use (ge11) was set to 0 Euro/year End of life costs of intermediate use (ge12) was set to 0 Euro Net present value of landfill management costs during intermediate use (NPVimucLM) was set to 0 Euro
Project drivers (ap8) is material-and-land-recovery	Recovered landfill volume value (ae2) was set to 0 Euro/m³
WtE plant is external (gate fee) or internal (ce1) is External	Costs for investment and operation of WtE plant (cec1) was set to 0 Euro/yr Annual costs for thermal treatment (WtE plant internal) (ACO6) was set to 2,536,800.0 Euro/yr (calculated as cec5) Costs for deposition of FA (fec3) was set to 0 Euro/yr Costs for ash treatment (dec1) was set to 0 Euro/yr Transport of non-ferrous metals (from bottom ash) NFM2 (dec2) was set to 0 Euro/yr Transport of ferrous metals (from bottom ash) FM2 (dec3) was set to 0 Euro/yr Revenues from electricity production (cec3) was set to 0 Euro/yr Revenues from heat production (cec4) was set to 0 Euro/yr Transport of fly ash & APC residues (to landfill) FA (dec6) was set to 0 Euro/yr Costs for deposition of AtL (fec2) was set to 0 Euro/yr Transport of bottom ash (to landfill) AtL (dec5) was set to 0 Euro/yr Valorization of materials (ARE3) was set to 3,173,681.0 Euro/yr (calculated as eec6+eec7+eec8+eec9+eec10) Current value of metals (eecm) was set to 672.34 Euro/Mg (calculated as (eec6+eec7+eec8)/(FMt*dec7+Cut*dec9+Alt*dec8))

Appendix 4

Orion results for landfill n°3301

Submit date: Jun 10, 2021 Response label: 3301

Results Cedalion

Select a landfill with high scores in Cedalion.

Fill in the name or reference of your chosen landfill: 3301

<< Back to Orion Dashboard

Is your landfill a mono landfill?

◯ Yes ◯ No ◉ I don't know

Do you find the waste in your landfill in this list?
Examples of monofills:

- (Fly) ashes
- Gypsum
- Lime
- Mine tailings
- Dredged waste
- Goethite

◯ Yes ◉ No

RDM available?

◯ Yes ◉ No

Is the history of your landfill linked to 1 type of production?

◯ Yes ◉ No

This is a mixed landfill

Does your landfill contain hazardous waste?

◯ Yes ◉ No

V < 20 000 m^3?

(•) Yes ( ) No

V/Va < 1,25?

(•) Yes ( ) No

Excavation feasible

Use ONTOL default values

NPV > -200 000/V?

( ) Yes (•) No

Detailed investigation with ONTOL: replace default values

NPV > -20 000/V?

(•) Yes ( ) No

Your stop:

Develop business case and use Orion Dashboard

If you would like to receive the results to your email, please enter it here: cuinera.isenborghs@ovam.be

CONCEPTUAL SITE MODEL

Appendix 5

ONTOL results for landfill n°3301

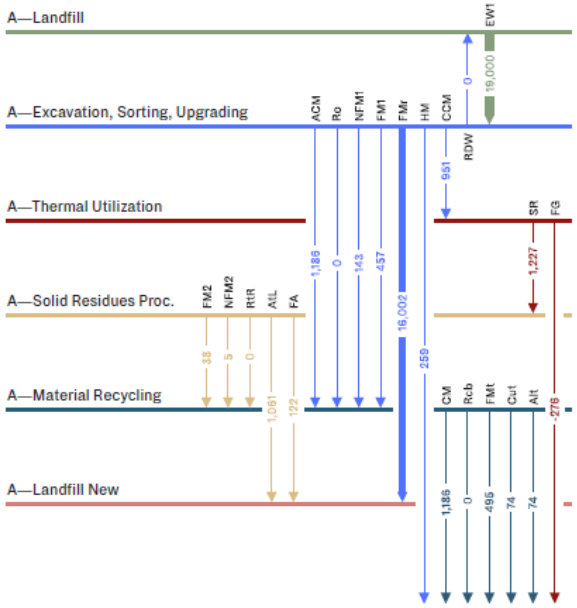
Online Tool for the Economic and Ecologic Evaluation of Landfill Mining

Project name: **SO-Schoten - L2**

Analysis type: Material flows, climate impact and economics of LFM project

Date of export: 10.07.2020

1-Results on the physical flows



ID	Description	Flow Mg/yr	Flow Mg
Excavation, Sorting and Upgrading			
EW1	Excavated waste	3,800	19,000
RDW	Residues (internally re-deposited) (total)	0	0
FMr	Residues (to external landfill) (total)	3,200	16,002
FM1	Ferrous metals (total)	91	457
NFM1	Non-ferrous metals (total)	28	143
Ro	Plastics to recycling (total)	0	0
HM	Hazardous materials (total)	51	259
ACM	Aggregates (total)	237	1,186
Waste Incineration			
CCM	Combustible materials (total)	190	951
FG	Off gas	-55	-276
SR	Solid residues (bottom ash, fly ash and APC residues)	245	1,227
AtL	Bottom ash to landfill	212	1,061
FA	Fly ash and APC residues	24	122
FM2	Fe scrap recovered	7	38
NFM2	NFe scrap recovered	1	5
RtR	Aggregates (derived from bottom ash) to recycling	0	0
Material Recycling			
FMt	Ferrous metals (total)	99	495
Cut	Copper (total)	14	74
Alt	Aluminium (total)	14	74
CM	Construction materials (aggregates)	237	1,186
Rcb	Plastics to recycling (total)	0	0

2-Results on climate impact

Processes	Burdens			Savings		
	Direct emissions [Mg Co_2 eq]	Indirect emissions [Mg Co_2 eq]	Avoided savings [Mg Co_2 eq]	Savings [Mg Co_2 eq]	Avoided direct emissions [Mg Co_2 eq]	Avoided indirect emissions [Mg Co_2 eq]
Reference Case	0	0	0	0	0	0
Emissions during LFM	0	0	0	0	0	0
Excavation, Sorting, Upgrading	0	163	0	0	0	0
Thermal utilization	0	4	0	0	0	0
Solid Residues Processing	0	7	0	0	0	0
Material Recycling	0	0	0	1,404	0	0
Landfill New	1,395	178	0	0	0	0
Re-deposited waste	0	0	0	0	0	0
Transport	0	199	0	0	0	0
Total	**1,395**	**551**	**0**	**1,404**	**0**	**0**

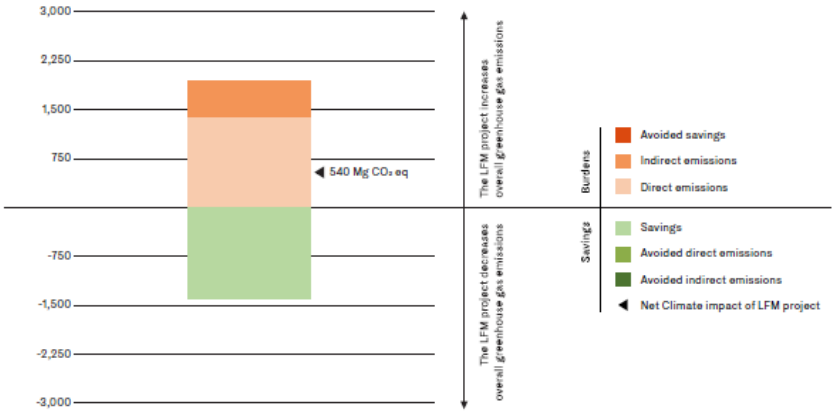
Direct emissions include greenouse gas emissions GHG that result from the waste itself (e.g. landfill gas). **Indirect emissions** include GHG emissions that result from the energy supply of different processes (e.g. energy demand for leachate treatment). **Avoided savings** include basically GHG emissions that would have been avoided in the reference case (e.g. substituting fossil fuels by utilizing landfill gas). **Savings** include avoided GHG emissins by substituting fossil fuel or primary raw materials. **Avoided direct emissions** include direct emissions that are avoided by the LFM project. **Avoided indirect emissions** include indirect emissions that are avoided by the LFM project.

Final results

Description	Value	Unit
Total burden	1,950	Mg CO_2 eq
Total saving	1,400	Mg CO_2 eq
Net climate impact of LFM project	542	Mg CO_2 eq
Specific net climate impact of LFM project	0.0285	Mg CO_2/Mg excavated

A negative net climate impact indicates savings of greenhouse gas emissions by the LFM project.

Global Warming [Mg CO_2 eq]



	[Mg Co_2 eq]
Direct emissions	1,395
Indirect emissions	551
Avoided savings	0
Savings	-1,404
Avoided direct emissions	0
Avoided indirect emissions	0

3-Results on the economy of LFM project

Initial costs

Description	Euro
Intermediate Use	0
Planning and Permits	65,000
Purchase of site & installations	0
Excavation, Sorting, Upgrading (investment costs)	32,300

Annual costs during project

Description	Euro/yr
Intermediate use	0
Landfill management	0
Excavation, Sorting, Upgrading (operational costs)	138,000
Thermal utilization	22,800
Solid residues processing	3,460
Disposal costs (external)	189,000
Transport costs	23,300

Annual costs after the end of the project

Description	Euro/yr
Aftercare costs of re-deposition landfill	0

One-time costs at the end of the project

Description	Euro
Final cover of re-deposition landfill	0
Landscaping, env. supervision & overhead	30,000
End of life costs of intermediate use	0

Annual revenues during project

Description	Euro/yr
Intermediate use	0
Revenues from landfill itself during time of intermediate use	0
Valorization of el & heat from LFG	0
Valorization of el & heat from WtE	0
Valorization of materials	71,400

Revenues at the end of the project

Description	Euro
Valorization of recovered land	2,180,000
Valorization of recovered landfill space	0
Valorization of used machinery	16,200

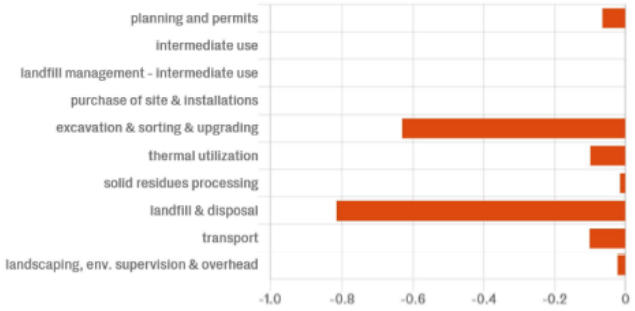
Calculation of the annual cash flows [Euro]

Year	Costs	Revenues	Avoided Revenues	Avoided Costs
0	474,000	71,400	0	2,200,000
1	376,000	71,400	0	21,800
2	376,000	71,400	0	21,800
3	376,000	71,400	0	21,800
4	406,000	2,270,000	0	21,800

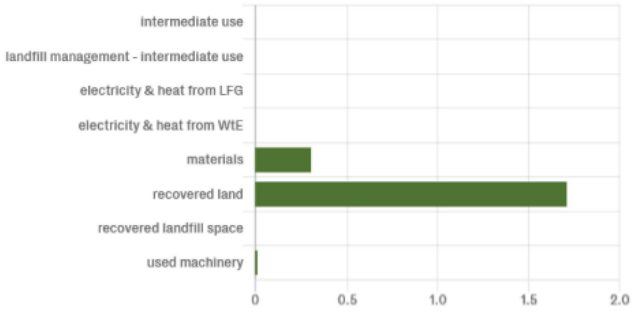
Final results

Description	Value	Unit
Net present value of costs	**-1.75**	**Mio Euro**
planning and permits	-0.065	Mio Euro
intermediate use	0.0	Mio Euro
landfill management - intermediate use	0.0	Mio Euro
purchase of site & installations	0.0	Mio Euro
excavation & sorting & upgrading	-0.631	Mio Euro
thermal utilization	-0.0988	Mio Euro
solid residues processing	-0.015	Mio Euro
landfill & disposal	-0.816	Mio Euro
transport	-0.101	Mio Euro
landscaping, env. supervision & overhead	-0.0224	Mio Euro
Net present value of avoided revenues	**0.0**	**Mio Euro**
Net present value of revenues	**2.03**	**Mio Euro**
intermediate use	0.0	Mio Euro
landfill management - intermediate use	0.0	Mio Euro
electricity & heat from LFG	0.0	Mio Euro
electricity & heat from WtE	0.0	Mio Euro
materials	0.309	Mio Euro
recovered land	1.71	Mio Euro
recovered landfill space	0.0	Mio Euro
used machinery	0.0127	Mio Euro
Net present value of avoided costs	**0.0**	**Mio Euro**
Total net present value of the project (TNPV)	**0.281**	**Mio Euro**
Specific net present value (SNPV)	**14.8**	**Euro/Mg**

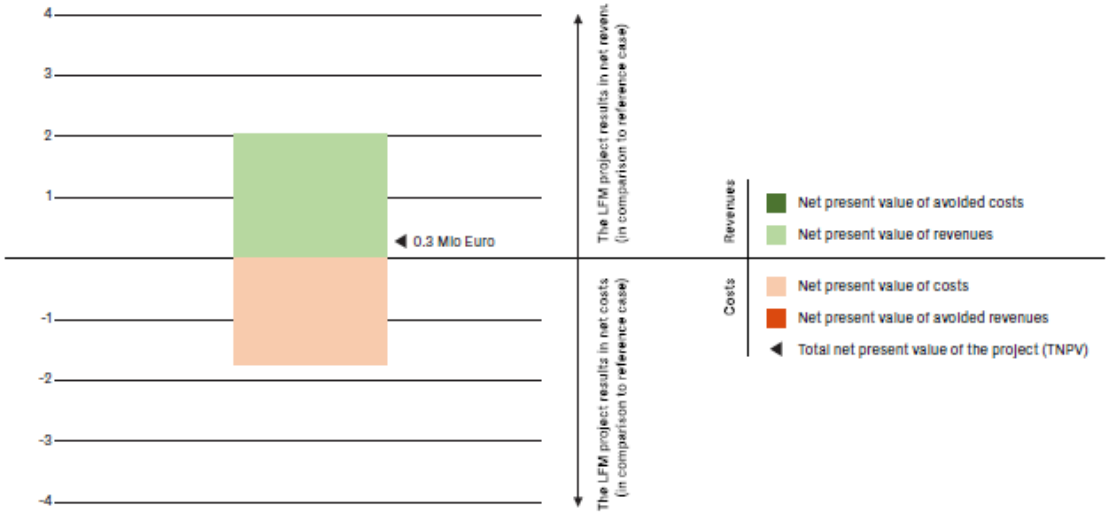
Net present value of costs [Mio Euro]



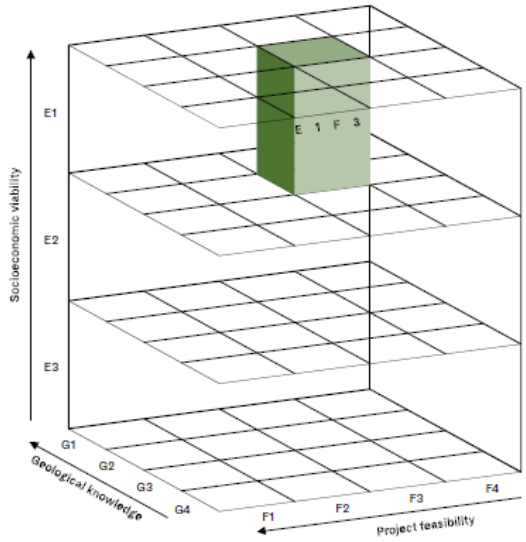
Net present value of revenues [Mio Euro]



Net present value



4-Results on resource classification of LFM project



- **Socioeconomic viability**

	SNPV (Specific net present value) 14.78 Euro/Mg		SNCI (Specific net climate impact) 0.03 kg CO_2 eq/Mg	
	>=	<	>=	<
E1	0	∞	-	-
E2	-15	0	-	-
	-30	-15	-∞	0
E3			0	∞
	-∞	-30	-	-

- **Project feasibility**

	Project status
F1	approved
F2	approval phase
F3	**approval not started**
F4	pre-exploration phase

- **Geological knowledge**

	Waste composition data
G1	very good
G2	**medium**
G3	poor
G4	unqualified estimate

Calculation of cut-off values

Cut off values for different parameters

Description	Cut off value	Current value	Required increase/ allowed decrease(*)
Price of regained land	41 Euro/m²	50 Euro/m²	83 %
Price of regained landfill space	0 Euro/Mg	0 Euro/Mg	
Price of valorized metals	116 Euro/Mg	551 Euro/Mg	21 %
Costs for thermal treatment	460 Euro/Mg	120 Euro/Mg	
Costs for disposal of residues	67 Euro/Mg	50 Euro/Mg	

(*) required increase in case that TNPV<0, allowed decrease in case that the TNPV>0