Co-funded by the Walloon region

Booklet: valorisation potential of landfills – examples

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1. Landfill remediation by waste excavation (Ghent) – *analysis by Arcadis Belgium*

1.1. Description of the site

The site is located in Wondelgem, Belgium, in an industrial zone in the port of Ghent (**Figure 1**). In the past, the site was used for the production of chemical components includes an above-ground landfill, used for production, construction and demolition waste. A chemical company started activities on the site in 1930. Currently, another company owns and operates the site.

Figure 1: aerial photograph of the site. The black polygon defines the location of the landfill.

1.2. History of the site

The chemical production activities started in 1928. Various chemical processes were carried out, whereby various waste streams were produced. There were two landfills on the site: one above ground (production waste + site demolition waste) and an underground (Barite landfill). Both were used in the period 1928-1966. A representation of the location of the two landfills is shown in **Figure 2**. In this report only the above-ground landfill is discussed. For this landfill, an Enhanced Landfill Mining project was carried out in the period 2017-2019.

The above ground landfill was used to deposit all production wastes from the site's mineral productions. These productions included sulfuric acid from pyrite, derived acids and salts such as iron, copper, sodium sulphate, hydrochloric acid and iron chloride. In addition to production waste, construction and demolition waste from the site was also deposited in the above-ground landfill. The landfill was eventually covered with a 30 cm thick layer of externally supplied earth from another site. There was no seal at the bottom.

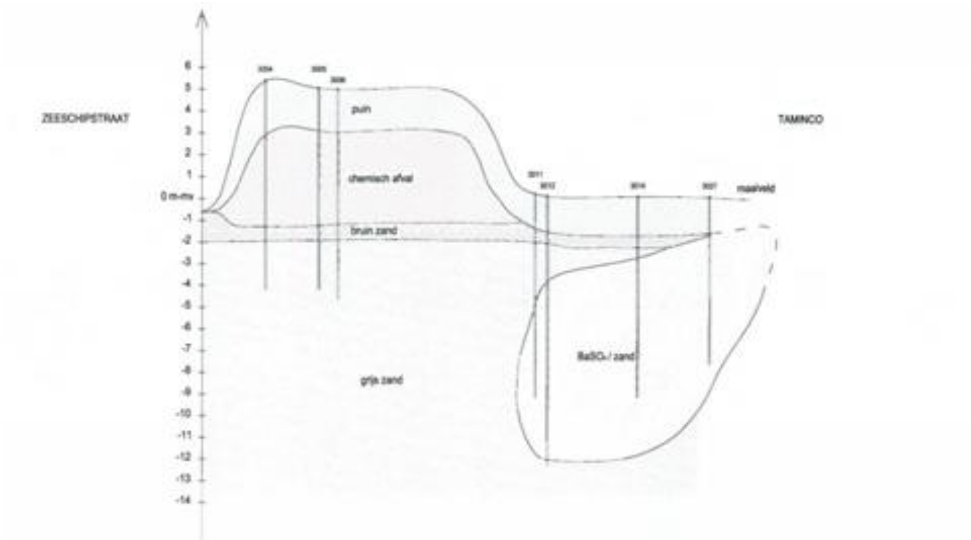


Figure 2: Schematic vertical representation of the landfill

1.3. Drivers for the landfill mining project

The reason for carrying out a soil remediation project (ELFM) is the groundwater contamination with heavy metals, barium, sulphates, inorganic and organic N-compounds and the contamination in the solid part of the earth. A potential risk of spreading cannot be ruled out for this contamination.

Due to sustainability considerations and because of the added value of the cleaned site, a conscious choice was made to fully excavate the aboveground landfill. Feasibility tests showed that 10% of the top soil of the landfill could be separated as recycled material (rubble, wood, plastic,...). In addition, due to the excavation of the above-ground landfill, an area of approx. 3 hectares was released, which could be completely redeveloped.

1.4. Stakeholder involvement

Arcadis Belgium NV was involved as a soil remediation expert in the project, and carried out various surveys on the site and set up the soil remediation concept. Arcadis Belgium NV also acted as an environmental supervisor during the excavation of the landfill. The contractor DEC carried out the excavation works for the above-ground dump. T

Originally, a BSP was set up by Arcadis in which the aboveground landfill was not excavated, but where the landfill was finished with a top seal. In the tendering phase, DEC subsequently proposed an alternative method, whereby the above-ground landfill was excavated, and the released materials were dumped, processed or recycled off site. This method had the following advantages:

- The contaminated soil was completely excavated, whereby the major part of the waste was removed;
- By excavating the aboveground dump, a zone of +/- 17,000m² will be available for further redevelopment.

Despite the fact that the alternative method proposed by DEC had a higher cost price compared to the original BSP (cover topsoil) prepared by Arcadis, it was opted to excavate the aboveground landfill.

1.5. Characterisation of the landfill content

The landfill is primarily an above-ground landfill where various waste products, originating from the various chemical processes, were deposited. These waste products mainly concerned mineral deposits. As mentioned above, the landfill was covered above ground with a debris containing supplied earth of about 30 cm thick. While drilling through the landfill, it was found that this cover layer is in reality only about 1.5 m thick. The original bottom is established at a depth of approximately 6.0 m-mv from the top of the landfill.

In the cover layer, mainly debris and brick-containing material is found. The landfill material that lies beneath this cover layer consists of a soil-like mass that varies greatly in colour (from light yellow, orange-red to brown-grey). Moderately fine sand is found from approximately 6 m below the ground.

The mass of the entire landfill was estimated at 173,400 tons, taking into account the following assumptions:

- Surface landfill: approximately 17,000 m² (feasibility study DEC: 18636.70 m²);
- Average thickness: 6 m (feasibility study DEC: 5.81 m);
- Volume land: 102,000 m³ (feasibility study DEC: 84 677 m³);
- Density of 1.7 tonnes / m³ (feasibility study DEC: 1.35 to 2.16 tonnes / m³).

Based on the available analyses of the soil in the landfill, a total mass of heavy metal contamination in the order of 2,900 tons can be estimated . This amount of contamination consists mainly of lead (43%), zinc (27%) and barium (20%) (**Table 1**).

Table 1: results of the available analysis of the soil in the landfill.

Parameter	Volume/mass (tons)	Percentage
Arsenic (As)	177,16	6%
Barium (Ba)	576	20%
Cadmium (Cd)	6	0%
Chrome (Cr)	6	0%
Copper (Cu)	83	3%
Mercury (Hg)	28	1%
Nickel (Ni)	5	0%
Lead (Pb)	1 244	43%
Zinc (Zn)	792	27%
TOTAL	2 917	100%

1.6. Description of the landfill mining operations

The works on the aboveground landfill started on 19/09/2017. The following preparatory work was started:

- General site design and mobilization of equipment
- Placing fencing
- Deforestation of the site
- Construction of a paved work floor in asphalt

In the period May 2018 - December 2019, the contaminated landfill material (height approx. 6 m) was excavated to a depth of approx. 1 m below ground level (like the original ground level). The excavated waste underwent several steps on site:

- Pre-treatment (fraction separation) on top of the chemical landfill:
    - Fine fraction (= material to be treated)
    - Screened excess (mainly masonry work rubble, concrete rubble and also plastic, wood and textile) with removal to a recognized recycling facility.
- Inspection of the material to be treated (waste) per 1,000 tons to determine the relevant process parameters so that the appropriate processing technique and the immobilizers can be determined.

- Processing (immobilization and/or structure improver) of the material to be treated on-site by adding the following additives:

  - sulphate source (type of gypsum-like additive)
  - pH correcting additive (type of calcareous additive)
  - iron source
  - phosphate source
  - structure improver

- Storage and inspection of the material to be treated

  - The material that did not need to be treated on site was immediately taken to the inspection area.
  - A selection sample was taken for each treated waste volume at the selection zone so that the correct final destination could be determined.

- Final processing or disposal. The following types of permit were necessary:

  - Landfill site category II;
  - Category I landfill site;
  - Crushing plant for rubble;
  - Recycling company for wood waste;
  - Recycling company for plastic waste:
  - Recycling company for textile waste;
  - Recycling company for mixed waste.

1.7. Waste revalorization

When drawing up the remediation plan, it was assumed that approximately 10% of the above-ground landfill material present is eligible for recycling or approximately 16,000 tons. During the execution of the excavation works, however, it turned out that in reality only about 1% had been recycled.

1.8. Rehabilitation of the site

The vacant space will be redeveloped in the future but a specific redevelopment plan is not available at the moment of writing.

1.9. Final results and benefits of the landfill mining project

The benefits of the excavation can be seen on the environmental and economic level. By removing the above-ground landfill material, the supply of additional contamination in the groundwater has been eliminated, and a further environmental impact is prevented. By a ful bulk ish excavation of overhead and supplementing it with new soil, there is also an economic value associated with the possible reuse of the vacant space

1.10. Laws and regulations applied

Since it concerns a soil remediation project, the Flemish soil decree applies.

1.11. Budget

The final excavation works were carried out with a budget of 6,711,770 EUR. These costs can be divided into the following sub-tasks:

- General costs (Preparation, coordination, deboning, SMEs,...): EUR 805,500 EUR
- Excavation works (Excavation, sieving, stabilization, transport and processing): 5,324,500 EUR
    - Construction work floor: 355,200 EUR
    - Excavation, temporary storage, stock management: EUR 432,000
    - Sieving and stabilizing: EUR 1,024,000
    - Waste transport and processing: EUR 3,513,300
- Additional work / overhead (mainly related to the UXO issue): 584,770 EUR

In addition to these costs, several periodic groundwater monitoring rounds will follow during which an evaluation is made of whether there is a stable condition in the groundwater. A budget of approximately EUR 1,000,000 is provided for this. This means that the total cost of the excavation & follow-up of the aboveground landfill comes to approximately 7,700,000 EUR.

The price of the vacant land area was assumed to be EUR 150 / m².

2. Nature development by relandscaping the landfill (Ravels) – *analysis by Sweco Belgium*

2.1. Description of the site

The site is an old landfill with a surface area of ~28,000 m² and ~40,000 m³ in volume, located in the Turnhouts Vennengebied (**Figure 3**). This area contains fens, heather and swamps which originated in abandoned clay pits that evolved into scientifically and biologically valuable areas.

Figure 3: Aerial photograph of the location of the landfill.

2.2. History of the site

The site was exploited as both a landfill for municipal waste and a roadbed for the old tram line from the beginning of the 20th century. Neither the municipality Ravels, nor the province of Antwerp have knowledge about the concerning landfill activities that have taken place on the location. The area on the opposite side of the road (**Figure 3**) are marked as landfills (former abandoned clay pits).

In 2012, the Canadabos (woodland) between the pond and the road was removed. At certain locations, the presence of construction waste, slag, ashes and municipal waste was observed at the surface.

2.3. Drivers for the landfill mining project

In this case, the driver is the environment. An industrial company has plans to expand their activities. Due to this decision, they have to compensate for nature area. Therefore, they will redevelop this site in a beneficial habitat for the European protected Bittern, Western marsh harrier and the Bluethroat (bird species). The Bittern needs a shallow water environment, hence the landfill will be excavated.

2.4. Stakeholder involvement

- OVAM: Sanctioned to perform the remediation of the landfill
- the accredited soil remediation expert assigned by OVAM
- Industrial company
- Landscape architect
- ANB: advisor concerning the redevelopment of the natural aspect.

2.5. Characterization of the landfill content

Site investigations started in 2003 to get an idea of the influence of the landfill on the environmental hygiene of soil and groundwater. The results displayed a pollution of heavy metals, mineral oil, PAH and EOX. A describing soil investigation was performed and consisted of 12 drillings until a depth of at least 3 m below the surface (and at least 0.5 m below the observed contamination). These 12 drillings allowed for the determination of the geometry of the landfill, and thus quantify the landfill content.

2.6. Description of the landfill mining operations

These have not started yet.

2.7. Waste revalorization

In the soil remediation plan three variants of remediation were considered. Following the BATNEEC[1] principle, the variant of applying a soil cover with a thickness of 0.5 m was chosen. The landfill material would be collected on a smaller surface near the Grote Baan, where it will serve as an embankment and an audio-visual buffer, before the soil cover is applied. Hereby, none of the polluted soil will be transported and no waste will be revalorized.

[1] best available techniques not entailing excessive cost

2.8. Rehabilitation of the site

The goal of the rehabilitation is eliminating the potential ecotoxic risks and contributing to the plans of creating a habitat of 30-50 hectares for the European protected Bittern, a shallow reed swamp. The site is suited to help accomplish this goal.

2.9. Final results and benefits of the landfill mining project

The benefit of the landfill mining operations is mainly environmental. The rehabilitation will reduce the potential spread of the pollution and also greatly reduce the ecotoxic risks for the environment. This is done by excavating the landfill and using it as an embankment to separate the street from the newly generated habitat followed by covering the landfill's surface with a 0.5 m soil cover. Afterwards the works will finish by modifying the aesthetics so that it fits in the environment.

2.10. Laws and regulations applied

The legal constraints were dictated by the Bodemdecreet and the Vlaamse Codex voor Ruimtelijke Ordening (VCRO).

2.11. Budget

The soil remediation plan estimates the total costs for this project at € 450 000. This will result in both a habitat for the Bittern of 20.000 m² which is an invaluable benefit for the environment, and expanding the industrial activities which is an economic benefit (increased revenue, job creation, ...). The land value of natural areas currently is more or less €1.5/m² which would strictly dampen the total costs by €30 000. This is just a secondary benefit since it is mostly to meet the guidelines of the EU.

3. Residential development by partial waste excavation (Izegem) – *analysis by Sweco Belgium*

3.1. Description of the site

The site is an old landfill with a surface area of ~4,500 m², located in Izegem, Belgium. This is an urban region (**Figure 4**), evolved from an agricultural area due to urban expansion.

Figure 4: aerial photograph of the landfill site in the research area

3.2. History of the site

The site was exploited as a clay- and sand-quarry from 1950 to 1960. After these activities, between 1970 and 1972, this location was used as a landfill. There is no information available on the composition of the landfill. However, in the past it was assumed that the concerning waste was of a municipal source. However, the preliminary soil investigation stated that it also concerns construction waste and possibly also hazardous waste. Currently, the site is used as a pasture.

3.3. Drivers for the landfill mining project

There is strong interest from the municipality of Izegem to upgrade this land to a residential area. Therefore, the driver for the project is to realize housing opportunities on the site.

3.4. Stakeholder involvement

- OVAM: The assessing government
- Potential buyer, initiator of the revalorization.

- The recognized remediation expert assigned by OVAM.
- Owner of the terrains.

3.5. Characterization of the landfill content

The site investigations started in 2014 in order to get an idea of the influence of the landfill on the environment (soil and groundwater). The results displayed a pollution of heavy metals and VOCl's. A describing soil investigation was performed, consisting of 11 drillings until a depth of 9 m below the surface and 10 monitoring wells. These drillings and wells allowed for the determination of the geometry of the landfill, and thus quantify the landfill content. The volume of the landfill is suggested to be 31 500 m^3, this is based on the depth of 7 m below the surface in which the pollution concentrations exceed the guidelines (4 500 m^2 x 7m = 31 500 m^3). However, the landfill volume that exceeds the remediation limits is confined to only 2 m below the surface which leads to a volume of 9 000 m^3 (4 500 m^2 x 2m). This provides different possibilities to approach the budget later in this report.

3.6. Description of the landfill mining operations

These have not started yet.

3.7. Waste revalorization

In the soil remediation plan, three variants of remediation were considered. Following the BATNEEC principle, the variant of a combination of excavation (0.5 m) followed by applying a soil cover (1 m) on geotextile has been chosen to be the most beneficial. Hereby the human toxicological and spreading risk will be diminished and the land will be available for building land with the predetermined safety measurements. Although the spreading risk will be diminished, the pollution boundaries extend beyond the borders of the landfill. Therefore there will still be leaching of the pollution into the groundwater.

3.8. Rehabilitation of the site

The goal of the rehabilitation is eliminating the potential human toxicological risk, diminishing the spreading risk of the pollution, as well as contributing to the plans of upgrading the land to building land.

3.9. Final results and benefits of the landfill mining project

The benefit of the landfill mining operations is mainly financial. Although the remediation works will reduce the potential spread of the pollution and also the human toxicological risks for the site, the main goal is to upgrade this land to building land and expand the urban area which will benefit both the possible investor and the city of Izegem.

3.10. Laws and regulations applied

The legal constraints were dictated by the Bodemdecreet and the Vlaamse Codex voor Ruimtelijke Ordening (VCRO).

3.11. Budget

As previously mentioned during the characterization of the landfill, different approaches to budget calculation are possible.

3.11.1. BATNEEC variant

Based on estimations in the soil remediation plan, the total costs of the project would be €200 000. This estimation is based on excavation of 1 m waste and applying a soil layer of 0.5 m in thickness. Since most of the pollution is considered to be fixed in the top layer, this should be a viable option. According to the output of ONTOL (**Figure 5**) the valorisation of the recovered land is €990 000 (based on the average price of building land of €220/m²), then the benefit of the project would be €990 000 - €200 000 = €770 000. However this would only be the case if the current value is €0/m², this is obviously incorrect.

Currently the area is classified as 'agricultural area with subsequently a residential destination'. If the land thus is considered as an agricultural zone, with an average price of €6.4/m² in West-Flanders, it would have current value of €28 800 (4 500 m² x €6.4/m²). Then the benefit of the project would be €990 000 - €200 000 - €28 800 = €761 200. This is probably still overestimated since the classification of the land leads to a more valuable price than normal agricultural land.

3-Results on the economy of LFM project

Initial costs

Description	Euro
Intermediate Use	0
Planning and Permits	11,000
Purchase of site & installations	0
Excavation, Sorting, Upgrading (investment costs)	0

Annual costs during project

Description	Euro/yr
Intermediate use	0
Landfill management	1,490
Excavation, Sorting, Upgrading (operational costs)	982,000
Thermal utilization	1,050,000
Solid residues processing	201,000
Disposal costs (external)	1,350,000
Transport costs	180,000

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	194,000
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	682,000
Valorization of materials	371,000

Revenues at the end of the project

Description	Euro
Valorization of recovered land	990,000
Valorization of recovered landfill space	0
Valorization of used machinery	0

Figure 5: Results of the ONTOL model

3.11.2. Excavation and treatment:

The soil remediation plan lists the price of soil to be excavated, transported and treated to be €50/metric ton.

Worst case, with a depth of 7 m and thus a volume of 31 500 m³, the mass of the landfill is estimated to be ~53 000 metric tonnes (based on an average density of 1.7) and would lead to a cost of €2 650 000 (53 000 metric tonnes x €50/metric ton).

Since the pollution is mostly fixed in the top layer, and a landfill depth of 2 m is considered, then the total volume to be excavated is 9 000 m³ or 15 300 metric tonnes. This would lead to a cost of €765 000 (15 300 metric tonnes x €50/metric ton).

This is of course only the excavation and treatment cost.

3.11.3. Excavation and recovery of materials

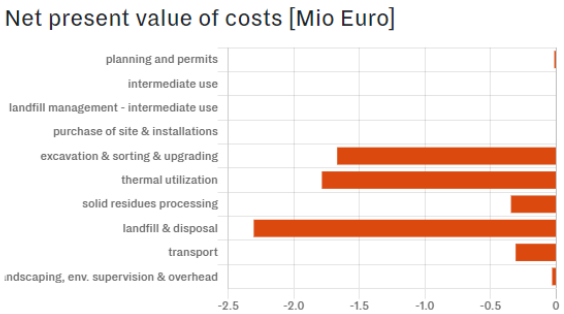
This scenario covers mining the landfill and recovering the materials. This is modelled in ONTOL. Since the composition of the waste has been roughly estimated and calculations were done with a significant amount of default values, the generated output will at most be an indicatory value.

Figure 6 displays the output for the worst case scenario when the landfill is considered to have a thickness of 7m, and thus a volume of 31 500 m³. The specific NPV, which will be generated from the project, would be €-76.6/metric ton if the project is carried out for 5 years. This translates to an estimated cost of €4 000 000. The estimated cost can be reduced to €3 200 000 if WtE is excluded.

In case the landfill is excavated, the sorting and processing of the materials can lead to a benefit.

Final results

Description	Value	Unit
Net present value of costs	**-6.44**	**Mio Euro**
planning and permits	-0.011	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	-1.67	Mio Euro
thermal utilization	-1.78	Mio Euro
solid residues processing	-0.342	Mio Euro
landfill & disposal	-2.3	Mio Euro
transport	-0.306	Mio Euro
landscaping, env. supervision & overhead	-0.0276	Mio Euro
Net present value of avoided revenues	**0.0**	**Mio Euro**
Net present value of revenues	**2.56**	**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	1.16	Mio Euro
materials	0.63	Mio Euro
recovered land	0.776	Mio Euro
recovered landfill space	0.0	Mio Euro
used machinery	0.0	Mio Euro
Net present value of avoided costs	**0.0463**	**Mio Euro**
Total net present value of the project (TNPV)	**-3.83**	**Mio Euro**
Specific net present value (SNPV)	**-76.6**	**Euro/Mg**



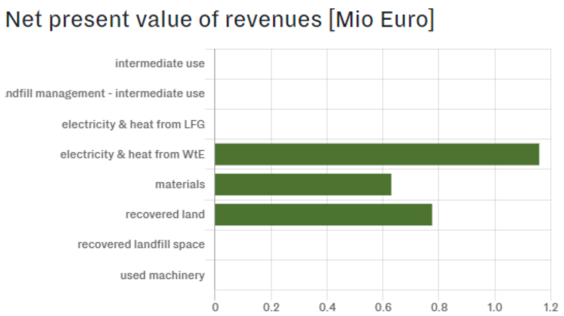
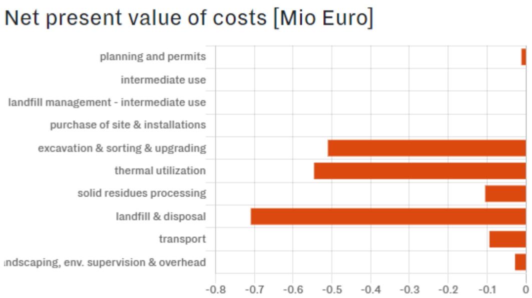


Figure 6: Results of the ONTOL model.

Figure 7 displays the output for the scenario in which the pollution is fixed in the top layer and only the first 2 m below the surface is considered as the landfill. This results in a volume of 9 000 m³. The specific NPV, which will be generated from the project, would be €-41.4/metric ton if the project is carried out for 5 years. This results in an estimated **cost** of €630 000. The estimated **cost** can be reduced to €442 000 if WtE is excluded.

Final results

Description	Value	Unit
Net present value of costs	**-2.0**	**Mio Euro**
planning and permits	-0.011	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	-0.51	Mio Euro
thermal utilization	-0.546	Mio Euro
solid residues processing	-0.105	Mio Euro
landfill & disposal	-0.709	Mio Euro
transport	-0.0936	Mio Euro
landscaping, env. supervision & overhead	-0.0276	Mio Euro
Net present value of avoided revenues	**0.0**	**Mio Euro**
Net present value of revenues	**1.32**	**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	0.355	Mio Euro
materials	0.193	Mio Euro
recovered land	0.776	Mio Euro
recovered landfill space	0.0	Mio Euro
used machinery	0.0	Mio Euro
Net present value of avoided costs	**0.0463**	**Mio Euro**
Total net present value of the project (TNPV)	**-0.633**	**Mio Euro**
Specific net present value (SNPV)	**-41.4**	**Euro/Mg**



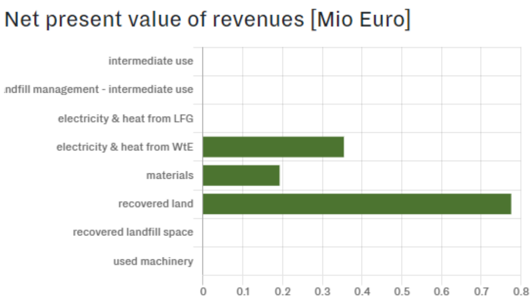


Figure 7: Results of the ONTOL model.

4. Eliminating odour nuisance by partial waste excavation (Begijnendijk) – *analysis by Sweco Belgium*

4.1. Description of the site

The site encompasses 2 former clay quarries which are situated in an agricultural area (**Figure 8**). In the past, the clay from the quarry was used by a nearby pottery. When the mining activities stopped, the quarry was used as a landfill. The 2nd quarry was dug later, in order to gather covering material to cover the landfill in the first quarry. The dumping of waste was stopped during the ’80s. At the surface level, the landfill is covered with a clay layer with an average thickness of 70 cm.

Figure 8: the site of the LFM project

The surface area of the landfill is 36.370m². The total volume of waste is estimated at ca. 508.750m³ and is present below the surface with a maximal depth of 20 meters.

In the west, a residential area is present and in the south, east and north, an agricultural function is present. A small stream flows at the northern edge of the site. A ditch that is situated in the northwest of the site probably ends in this stream. A number of small ponds are also situated at the northern end of the site.

As a consequence of the former landfill activities, there were repeated complaints from local residents about odour nuisance in the past. Due to the biological activity of the landfill, soil subsidence was measured with a range of maximum 1,5 meter at the ground level. Although the landfill activities were stopped more than 30 years ago, the actual situation can lead to an evaporation of gases, odour nuisance and further subsidence.

4.2. History of the site

From 1963 up till 1975, the site was a clay quarry. From 1976 up till 1985, the site was used as a landfill for non-poisonous, industrial waste. A permit was delivered for these activities. The following steps were taken:

- The landfill activities initially took place at the 1st clay quarry. Waste was dumped at a maximum depth of ca. 20 m ground level;
- The 2nd clay quarry was used to gather covering material for the 1st quarry;
- Starting from ca. 1985, landfill activities also took place at the 2nd quarry;
- Presumably, inert waste (in particular wood and plastics) was still dumped at the site in 1988 to level sinks that originated from degradation of the belowground waste;
- Since the ending of the landfill activities, the ground level at the landfill site is said to have dropped by 1,5 – 2,0m. This lowering is caused by the degradation of the waste.

The site is currently used as a horse pasture.

4.3. Drivers for the landfill mining project

The main driver for the project is the potential negative impact from the landfill on the environment. During the most recent soil investigation, soil contamination was detected with metals and aromatic organic compounds. Elevated levels of polluting compounds were also detected in the groundwater and the leachate.

In addition, local residents complained numerous times about the odour nuisance that originated from the landfill. The odour is caused by the decaying of waste and the subsequent formation of landfill gas.

The driver in this project is the environment but also the biological activity is an important secondary risk. The landfill is located in an area where the land value and pressure is relatively high.

4.4. Stakeholder involvement

Currently, the OVAM is conducting an assessment of the (potential) risks which might arise from the landfill. So far, no agreements for cooperation with other stakeholders were signed.

OVAM asked SWECO to evaluate the possible scenarios for landfill mining.

4.5. Characterisation of the landfill content

The landfill was authorized to accept non-poisonous, industrial waste. However, it is not clear what kind of material was dumped at the landfill in reality. According to testimonies from local residents, the following material was dumped at the site:

- Black blocks (possibly consisting of lead) and white powder;
- Waste from a nearby hospital;
- Shoes and leather waste from a shoe factory ;
- Barrels from unknown origin. These were dumped during the night and immediately covered with ground.

During the earlier research at the site, wood, metal and fly ashes were found in the landfill. The majority of the landfill however seems to contain rubble (stones and bricks) and household waste. The formation of landfill gas at the site also indicates that a significant amount of organic matter – containing household waste is present at the site.

4.6. Description of the landfill mining operations

The landfill mining project has not yet started.

4.7. Waste revalorization

The landfill mining has not yet started. Due to uncertainties about the composition of the waste material, only an indicative estimation of the profitability of a landfill mining project at the site can be made at this stage.

Earlier, methane concentrations at the landfill site were measured and considered to be exploitable. This means that the landfill gas which is generated at the site, might be used in a profitable way for the production of heat and electricity. Because the landfill was covered with a clay soil layer, the methane can be conserved in the landfill during a longer period.

4.8. Rehabilitation of the site

Currently, no specific plans for the redevelopment of the site are known. The site is situated in an agricultural area, and in the direct vicinity of a residential area. The main obstacles that might constrain the redevelopment of the site, are the odour nuisance, the subsidence's that occur at ground level do to the degradation of the waste, and the presence of pollution.

4.9. Final results and benefits of the landfill mining project

At this stage, the removal of the odour nuisance, pollution and prevention of further soil subsidence might be considered as the main advantages of a landfill mining project at this site. However, at this moment, a first estimation of the amount of resources that might be recovered in a profitable way, is made.

In the longer term, the site might fulfil a productive role as an agricultural site. Given its location next to a residential area, future redevelopment of (part of) the site to a residential area cannot be excluded.

4.10. Laws and regulations applied

The legal constraints were dictated by the *Bodemdecreet* and the *Vlaamse Codex voor Ruimtelijke Ordening* (VCRO).

4.11. Budget

The site is located in an agricultural area and borders to a residential area. A potential redevelopment of the site to a residential area might therefore be possible. Given the significant difference in value between farmland and building land, an ONTOL simulation was performed for both scenarios. The following prices are used during the modelling:

- Farmland: 4,26 euro/m²
- Building land: 182 euro/m² (specific for the region of the landfill)

In case the site would be used as farmland after landfill mining, the costs of the project will be 43,5 million euro. In case the site would be used as a residential area, the total costs of the project will be 38,2 million.

It should be noted that a complete excavation of the landfill site was simulated in these scenarios. Such an excavation is not necessary to eliminate all risks and concerns that arise from the landfill. A remediation plan with an excavation of the top layer till 1m depth can eliminate all risks. The economical balance of the project is negative if the site would be used as farmland. If the site would be used as building land, the project is profitable, with an anticipated profit of about 2,45 million euro (**Figure 10**).

In conclusion, in order to evaluate the profitability of the landfill mining project, an estimation has to be made of the soil contamination that is present at the site, the composition of the waste and the measures that should be taken in order to safely redevelop the site.

Figure 9 shows the output from ONTOL for a possible remediation concept of the top layer. In this scenario, the site would be redeveloped to farmland. The project cost would be €2 680 000 (€1 220 000 thermal utilization excluded). **Figure 10** shows the output from ONTOL for the same remediation concept but for a different rehabilitation concept: o residential land use. This project benefit would be €2 450 000 (€4 000 000 thermal utilization excluded).

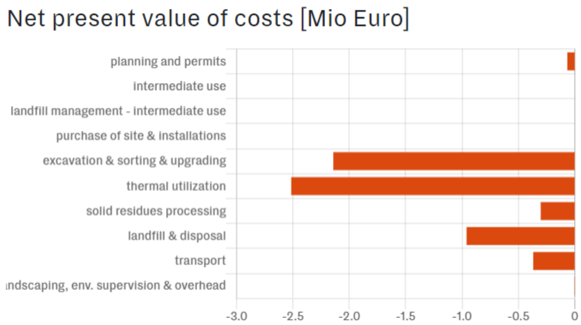
It should be mentioned that the future remediation plan has to include the effects on human toxicological risks, spreading risks, soil subsidence, evaporation of gases, etc. The recovering of materials can optimize the excavation works in case a part of the landfill has to be physically removed to reach all the goals of the remediation plan. Otherwise, the processing of the excavated materials can be optimized with:

- On-site sorting and processing;
- Limited transport costs, on-site storage of fine soil fractions (less transport costs and CO_2-emissions…);
- (On-site energy generation).

The benefit of this project depends on the future use of the land.

Final results

Description	Value	Unit
Net present value of costs	**-6.35**	**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	-2.14	Mio Euro
thermal utilization	-2.51	Mio Euro
solid residues processing	-0.301	Mio Euro
landfill & disposal	-0.959	Mio Euro
transport	-0.367	Mio Euro
landscaping, env. supervision & overhead	-0.00426	Mio Euro
Net present value of avoided revenues	**0.0**	**Mio Euro**
Net present value of revenues	**3.48**	**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	1.05	Mio Euro
materials	2.31	Mio Euro
recovered land	0.127	Mio Euro
recovered landfill space	0.0	Mio Euro
used machinery	0.0	Mio Euro
Net present value of avoided costs	**0.187**	**Mio Euro**
Total net present value of the project (TNPV)	**-2.68**	**Mio Euro**
Specific net present value (SNPV)	**-46.1**	**Euro/Mg**



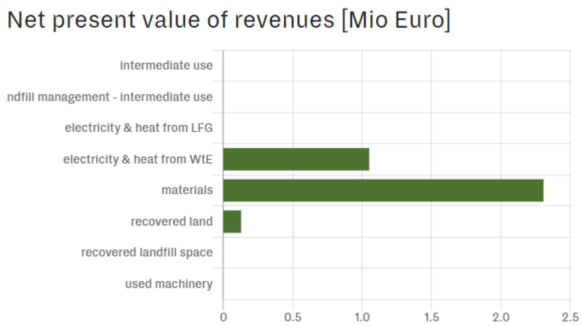
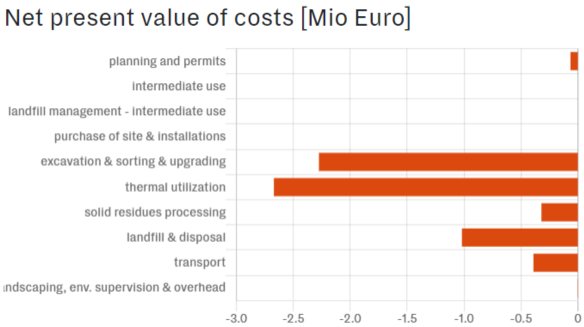


Figure 9: Output of the ONTOL model - rehabilitation to farmland after excavation of the top layer

Final results

Description	Value	Unit
Net present value of costs	**-6.74**	**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	-2.27	Mio Euro
thermal utilization	-2.67	Mio Euro
solid residues processing	-0.32	Mio Euro
landfill & disposal	-1.02	Mio Euro
transport	-0.39	Mio Euro
landscaping, env. supervision & overhead	-0.00426	Mio Euro
Net present value of avoided revenues	**0.0**	**Mio Euro**
Net present value of revenues	**9.01**	**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	1.12	Mio Euro
materials	2.45	Mio Euro
recovered land	5.45	Mio Euro
recovered landfill space	0.0	Mio Euro
used machinery	0.0	Mio Euro
Net present value of avoided costs	**0.187**	**Mio Euro**
Total net present value of the project (TNPV)	**2.45**	**Mio Euro**
Specific net present value (SNPV)	**39.7**	**Euro/Mg**



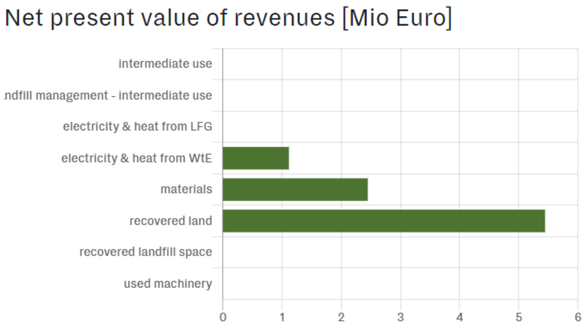


Figure 10: Output of the ONTOL model - rehabilitation to farmland after excavation of the top layer

5. Safeguarding food production by landfill mining (Meeuwen-Gruitrode) – *analysis by Sweco Belgium*

5.1. Description of the site

The site is an old landfill with a surface area of ~11300 m². It concerns an abandoned quarry for pebble-stone, located in Meeuwen-Gruitrode, Belgium. Currently, this region is an agricultural area and contains mostly pastures and some small woods (**Figure 11**).

Figure 11: Aerial photograph of the landfill site area.

5.2. History of the site

The history of this site is not entirely clear. From 1955, the site was exploited as a quarry for pebble-stone. Based on aerial photographs, the landfilling began around 1970-1971, when the city of Bree was the owner. The landfilling activities stopped in 1983 and the landfill was covered by 1986. Since 1983, no activities have taken place on this piece of land.

Available information indicates that the waste consisted of municipal waste and inert materials.

5.3. Drivers for the landfill mining project

The current land use on the site is agriculture. However, with the current contamination situation, the question rises if there are potential risks involved with growing crops or cattle grazing. Therefore, the main driver of the landfill mining project would be to eliminate potential risks to the environment and human health.

In another scenario, the site could be redeveloped and upgraded . This is often interesting in urban areas where the land pressure and value is high. Regardless, this region is mainly rural, with some forest in its proximity (**Figure 12**). Therefore, an agricultural or natural function is preferred.

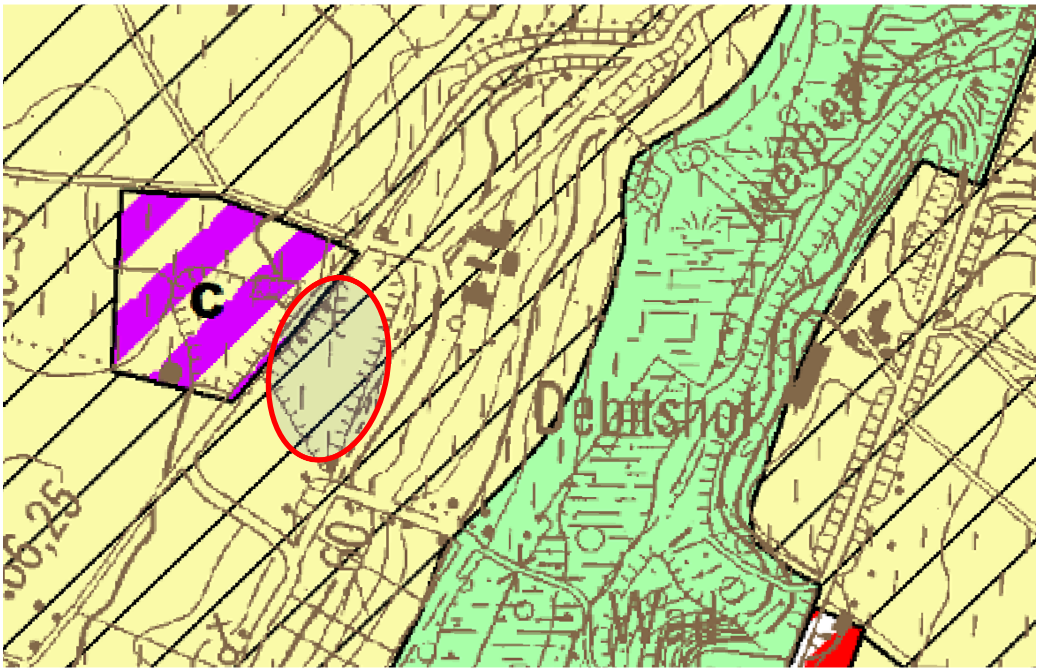


Figure 12: Gewestplan of Flanders (yellow = agricultural, green = woodland)

Another possibility is to start an Enhanced Landfill Mining project. The University of Ghent did a geophysical study on this particular site in which they investigated the conductivity beneath the surface. This was done by using an electromagnetic induction sensor to map the area. Due to geomorphological properties, the area was divided in two zones. Zone 1 had a higher overall conductivity in the soil than zone 2 (**Figure 13**) and will therefore probably be enriched in conducting materials.

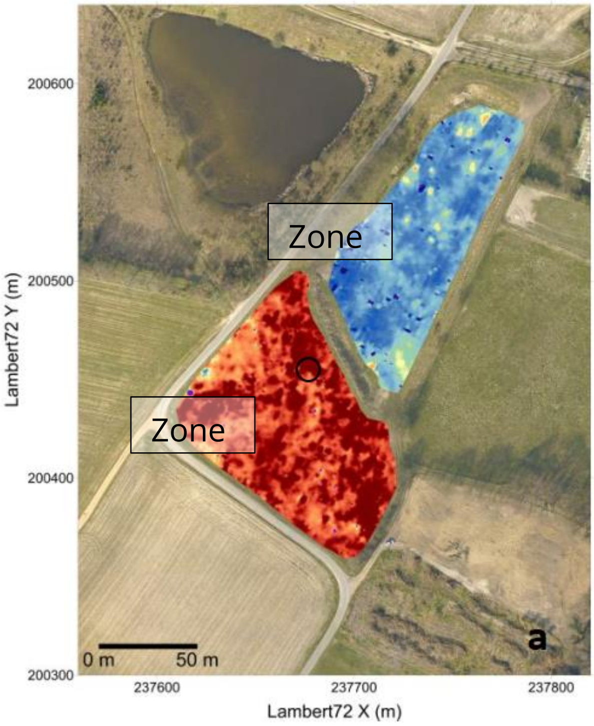


Figure 13: Conductivity map of the area (red = high conductivity and blue = low conductivity)

5.4. Stakeholder involvement

- OVAM: the assessing government
- OVAM: owner of the terrain
- Soil remediation expert assigned by OVAM

5.5. Characterization of the landfill content

A preliminary site investigation started in 2014, in order to get an idea of the impact of the landfill on soil and groundwater. The results showed a contamination with heavy metals, mineral oil and PAHs. Afterwards, a describing soil investigation was performed , which allowed to determine the geometry of the landfill, and thus quantify the landfill content. The volume of the landfill is suggested to be 84 000m³, with a depth of 7 m below the surface. Drilling cores have shown remaining plastics, textiles, glass, asbestos and bricks as landfill content. The groundwater is polluted with chlorinated hydrocarbons but the spreading risk towards the environment is rather low.

5.6. Description of the landfill mining operations

These have not started yet.

5.7. Waste revalorization

Currently, there are two possibilities concerning the treatment of this particular site:

1. Excavating the landfill and refilling it with clean soil to eliminate any potential risk to the environment;
2. Enhanced landfill mining.

The concurrent phase in the project is the valorisation phase where these options are compared.

5.8. Rehabilitation of the site

The goal of the rehabilitation is eliminating the potential human toxicological risk, diminishing the spreading risk of the pollution, as well as upgrading the land to higher quality agricultural land or woodland.

5.9. Final results and benefits of the landfill mining project

The benefit of the landfill mining operations is mainly environmental. The rehabilitation will reduce the potential spread of the pollution and also greatly reduce the ecotoxic risks to the environment. This is done by excavating the landfill and filling it up with clean soil.

5.10. Laws and regulations applied

The legal constraints were dictated by the Bodemdecreet and the Vlaamse Codex voor Ruimtelijke Ordening (VCRO).

5.11. Budget

As previously mentioned, different approaches to the budget estimation are possible, in function of the following options:

1. Excavation, followed by refilling with clean soil and covering with a soil layer;
2. Enhanced landfill mining: with landfill gas/material energy recuperation and material recycling;
3. Enhanced landfill mining: without landfill gas energy recuperation;
4. Enhanced landfill mining: only material recycling.

In the first scenario, all potential contamination risks are eliminated. Based on expertise, the costs for excavating, transporting, treating and refilling were estimated to be €~100/m^3. For this particular site, that would be a total cost of €8 400 000. This results in a cost of €70/metric ton.

For the other options, simulations were performed using ONTOL with the available information from the describing soil investigation. None of the technical information regarding the conversion to energy or the material recycling is known. Therefore, these simulations were based on the default values suggested by ONTOL or estimations.

5.11.1. Conclusion

There were several options considered for the remediation of the former landfill site in Meeuwen-Gruitrode. The results of the cost estimations for these options are shown in **Table 2**. The excavation and refilling option comes forward as least profitable with a cost of €70/metric ton, whereas the option of Enhanced landfill mining with only recycling materials comes out as most profitable.

Table 2: Cost estimations for the different options.

Option	Cost (in €/metric ton)
Excavation, followed by refilling with clean soil and covering with a soil layer	70
Enhanced landfill mining: with landfill gas/material energy recuperation and material recycling	66.4
Enhanced landfill mining: without landfill gas energy recuperation	66
Enhanced landfill mining: only material recycling	43

The most profitable option, enhanced landfill mining with only material recycling, will lead to a project cost of €5 200 000. An excavation of the top layer (50 cm) and a cover with a clean soil layer is estimated on € 1 000 000.

It should be mentioned that although the Enhanced landfill mining comes out as most beneficial, chances are small that it will actually result in benefit. The waste composition was estimated based on drilling logs and technical specifications were applied with default values. Therefore, further research concerning waste composition is necessary.

6. Development of a new business park by landfill remediation (Vilvoorde) – *analysis by Sweco Belgium*

6.1. Description of the site

The site concerns an old landfill with a surface area of ~30,000 m², located in Vilvoorde/Machelen (former Renault site) (**Figure 14**). Currently, the site is not in use.

Figure 14: Aerial photograph of the location of the landfill site.

6.2. History of the site

The site and surrounding parcels, which were once a swamp, were exploited as a landfill for municipal waste from 1950 to 1973. After purchase by Renault, the terrain was partially excavated until the level it is today. The surface level used to be 3 m higher. During the landscaping, workers were forced to wear gas masks because of harmful gas escaping from the landfill. Therefore, a concrete layer of more than 30 cm thick was applied to prevent gas discharge into the working space.

The former Renault buildings have been demolished, while the concrete floor and asphalt remained. Several companies have been exploiting the site for their activities. The largest part of the area was used as temporary storage of new cars. Currently, the site is not in use. However, there are plans to redevelop the site to a business park.

6.3. Drivers for the landfill mining project

In this case, the driver is mainly environmental. The goal of the remediation project is to remove the risk of spreading and the risk it has concerning the soil quality and safety hazards for people and the environment. The remediation has to enlarge the possible land uses (not only parking but also business park, green zones etc.).

6.4. Stakeholder involvement

- OVAM: Sanctioned to perform the remediation of the landfill
- remediation expert assigned by OVAM
- owner of the terrains, initiator of the revalorization and redevelopment of the terrain

6.5. Characterization of the landfill content

The preliminary site investigations started in 2015, in order to get an idea of the impact of the landfill on soil and groundwater contamination. Investigations on surrounding areas started in 2007, also concerning former landfill activities. The results showed a pollution of mineral oil, BTEX and trimethylbenzene in the soil and groundwater. A describing soil investigation was performed, which allowed for the determination of the geometry of the landfill, and thus a quantification of the landfill content. Additionally, during the remediation plan, a soil air investigation was performed as well together with flux chamber measurements to characterize the gas discharge from the soil.

6.6. Description of the landfill mining operations

These have not started yet.

6.7. Waste revalorization

In the soil remediation plan, three variants of remediation were considered. Following the BATNEEC principle the variant of excavating soil, until the pollution has reached certain remediation values, came out as most viable. Hereby, the excavated soil will be transported and treated by a licensed processor. Additionally, drains will be installed beneath the buildings at 1 m below the surface which will capture gas discharge from the soil.

To evaluate whether mining of the landfill (not considered in the remediation plan) is a viable option, several scenarios are worked out with ONTOL in the Budget section below.

6.8. Rehabilitation of the site

The goal of the rehabilitation is eliminating the potential ecotoxic risks and redeveloping the terrain as a business park.

6.9. Final results and benefits of the landfill mining project

The benefit of the landfill mining operations is mainly environmental. The rehabilitation will reduce the potential spread of the pollution and also greatly reduce the ecotoxic risks. This is done by excavating the landfill and its polluted soil. Currently, the site has a large amount of unused space available, which will be valued when the redevelopment takes place and the business park is developed.

6.10. Laws and regulations applied

The legal constraints were dictated by the Bodemdecreet and the Vlaamse Codex voor Ruimtelijke Ordening (VCRO).

6.11. Budget

To evaluate whether mining of the landfill (not considered in the remediation plan) is a viable option, several scenarios are worked out below. The terrain will be used again as a business park, so land recovery is considered in every scenario. Since the land use does not change over time, the land recovery will be break-even.

1. No material recycling, no waste to energy, no landfill gas to energy
2. No waste to energy, no landfill gas to energy, only material recycling
3. No landfill gas to energy, only material recycling and waste to energy
4. No waste to energy, only material recycling and landfill gas to energy
5. Material recycling, waste to energy and landfill gas to energy

Simulations were performed using ONTOL with the available information from the describing soil investigation. None of the technical information regarding the conversion to energy or the material recycling is known. Therefore, these simulations were based on the default values suggested by ONTOL or estimations.

6.11.1. Conclusion

The results of the budget estimations per scenario are summarized in **Table 3**. Applying all options (material recycling, waste to energy, landfill gas to energy and land recovery) results in a NPV of -70.2 euro/metric ton. When only land is recovered, a NPV of -92.3 euro/metric ton is estimated. This means that the effort of valorising at least some resources can compensate some of the costs. Furthermore, all intermediate options are more profitable than a ‘land recovery only’ project.

Table 3: Simulation of the budget for the different options in ONTOL. Results can be found in the Appendix

Scenario	NPV (euro/metric ton)	Project cost (Mio €)
Land recovery	-92.3	28,3
Material recycling and land recovery	-81.0	24,8
Material recycling, WtE and land recovery	-68.9	21,1
Material recycling, LFG to energy and land recovery	-82.3	25,2
Material recycling, WtE, LFG to energy and land recovery	-70.2	21,5

The most profitable scenario is the one in which material recycling, waste to energy and land recovery all take place. This means that the costs for converting landfill gas into energy are larger than the revenue. It should be mentioned that the project cost includes transport costs and cost generated by the disposal of waste. A scenario with landscaping, if possible, is more profitable than the calculated scenarios and can reduce the transport costs. A scenario with only the recovering of the waste (mostly stones and inert waste) will result in less disposal of waste and thus less costs.

7. Reintroducing a landfill area in the Economical Network of the Albert Channel (Schawijk) – *analysis by Sweco Belgium*

7.1. Description of the site

The majority of the landfill site is located in an agricultural area, for which the parcels are privately-owned (**Figure 15 and 16**). The area pf the ma,dfomm os 67.757 m². Another, smaller part of the landfill is located in an area for public utility. This is owned by the Governmental Agency for Roads and Traffic but at the moment, it is not being used. The area is easily accessible thanks to the presence of the highway (E34) in the north of the landfill, as can be seen on **Figure 15**. Less than 2 km to the North, a canal is located (Albertkanaal) which is directly connected to the harbour of Antwerp.

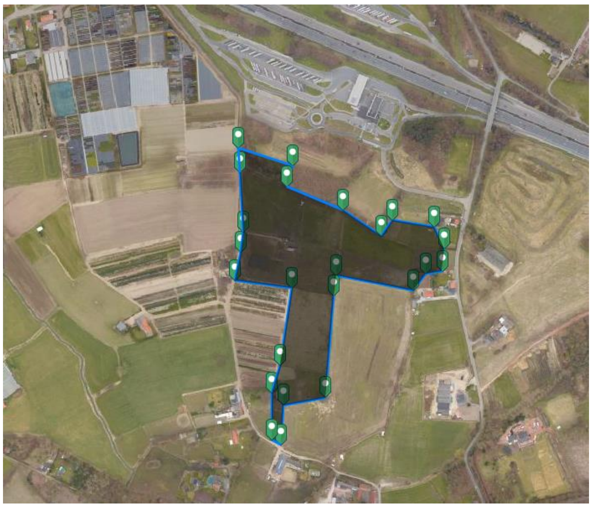


Figure 15: Aerial photograph of the landfill area

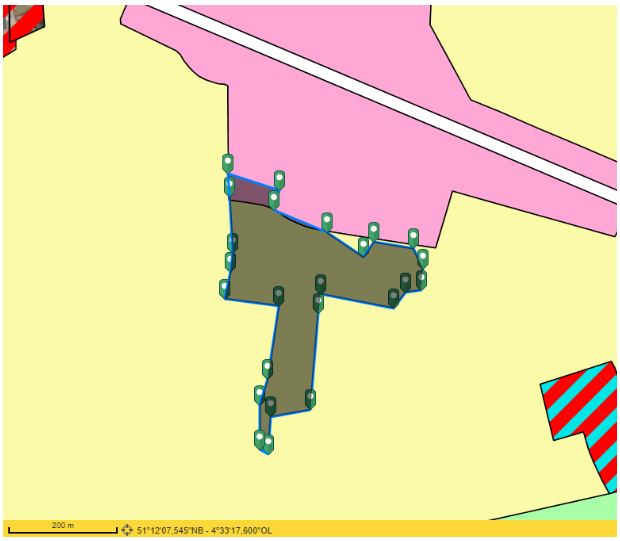


Figure 16: Outline of the landfill on the Flemish Gewestplan (yellow: agriculture, purple: public use (highway rest stop)

7.2. History of the site

Before the landfill activities, the site was used for the excavation of sand. The municipality Ranst has confirmed that household waste was dumped in the old quarries between 1960 and 1982. There is no detailed information available about the type of waste that was landfilled. After the dumping activities, a thin layer of soil was placed over the landfill as a cover. Because of the thin layer, the waste is visible at the surface at different locations.

The current land use of the site is mostly grassland, grazed by animals (not used for consumption). Other uses of the site are corn cultivation (agriculture) and usage as a horse race track (recreation).

7.3. Drivers for the landfill mining project

The first driver for this project is the odour nuisance it causes for the owners and users of the site. This is probably the result of erosion since the waste is appears at the surface at different locations.

The second driver is environmental and is related to the soil contamination with heavy metals and PAH. Due to the presence of waste at the surface level, a direct human toxicological risk is present. The spreading risk is also acknowledged but is only local at the ditch crossing the landfill. The ongoing soil investigation already showed that the contaminants involve some risks and preliminary results recognize potential spreading and risks to humans. The area is also suspicious for asbestos, but this must be investigated further.

As stated before, the location of the area is interesting given the nearby location of the highway (E313) and the Albertkanaal. Furthermore, the site is located in an area that is described as the Economical Netwerk Albertkanaal (ENA) and connects Ranst with a lot of other townships and the harbour of Antwerp. The ENA is shown in **Figure 17**.

Ranst is known for its former sablon mining sites that are now all filled with waste. It is estimated that in Ranst there is an approximate area of more than 200 ha of known landfills. This aspect should also be taken into account for further possible developments. Some areas in the ENA are reserved for nature, other possible locations can be interesting for a business park or industrial site. However, this landfill is located in an agricultural area and that is also the most obvious future use.

Figure 17:The location of the study area within the ENA (Economical Network around the Albert canal

7.4. Stakeholder involvement

- OVAM: Sanctioned to perform the remediation of the landfill;
- Owners: there are multiple owners of the different parcels whom do not have an active function at this moment.

7.5. Characterisation of the landfill content

The landfill composition was characterized with drillings during the soil investigation. The following types of waste were observed: glass, metal, wood, paper, styrofoam, ashes, rubble, plastics, asbestos, embers, tiles, bricks, concrete, plaster, lime, household waste,…

The area of the landfill is estimated at 68.757 m² with a volume of 202.865 m³ and a thickness of 1-4 m below the surface. It is assumed that the soil is contaminated with heavy metals and PAH and the groundwater with chromium. In the ditch located within the landfill, the ground is contaminated with heavy metals, PAH and PCB.

7.6. Description of the landfill mining operations

These have not started yet.

7.7. Waste revalorization

The soil remediation plan from 2010 stated that for this case, the best remediation option is partial excavation followed by the application of a soil cover. After excavation, a geotextile cloth will be placed in the bottom of the pit to indicate the start of the landfill material. The pit will be filled with clean soil.

7.8. Rehabilitation of the site

Considering the location of the site, with its destination type and the destination of the surrounding area, changing the current land use is not ideal. The preliminary results of the soil investigation showed that the contaminations on the site present a human risk. It is therefore not recommended to change the land use, for example to agricultural (consumption) use. The possibilities of intermediate use are therefore limited. The mining of the site can be interesting considering it is located in the ENA, as described earlier (regional re-use of stones and sand after mining and processing of waste).

7.9. Final results and benefits of the landfill mining project

The benefit of the landfill mining operations would be mainly environmental. The rehabilitation will reduce the potential spread of the pollution and also greatly reduce the ecotoxic risks for the region. This is done by excavating the landfill and filling it up with clean soil so that the land could be used to grow crops.

An important factor is the location of the parcel in the ENA. Development of this area could lead to economic benefits for the region (e.g. employment opportunities). However, currently this region is mainly agricultural. Thus, there is no other viable option at the moment than to rehabilitate this parcel as farming land.

7.10. Laws and regulations applied

The legal constraints were dictated by the Bodemdecreet and the Vlaamse Codex voor Ruimtelijke Ordening (VCRO).

7.11. Budget

Currently there are several options to be evaluated:

1. Excavation of the whole landfill, refilling with clean soil, no enhanced landfill mining
2. Partial excavation (2 m), refilling with clean soil, no enhanced landfill mining
3. Excavation, material recovery and Waste to Energy
4. Excavation and only material recovery

Since there is no information available on landfill gas, the option of landfill gas to energy has not been evaluated separately.

7.11.1. Conclusion

There were several options available for the future rehabilitation of the former landfill site in Schawijk. The results of the budget estimations for these options are shown in **Table 4**. The excavation with material recovery and WtE comes forward as least profitable with a cost of €35.3/metric ton, whereas the option of excavation with only recycling materials comes out as most profitable. Remarkable is that the benefit of producing energy is diminished by the amount of costs that are generated by the process.

It should be mentioned that although the material recycling comes out as most beneficial, chances are small that it will actually result in a benefit. The waste composition was estimated based on drilling logs and technical specifications were applied with default values. Therefore, further research concerning waste composition and these techniques could result in more accurate information.

It needs also to be mentioned that the ENA-project can create local needs for materials (stone rubble, use of sand in dikes…).

Table 4: Cost estimation results of the ONTOL model for the different options that were considered

Option	**Cost (in €/metric ton)**	**Cost (in MIO €)**
Excavation of the whole landfill, refilling with clean soil, no enhanced landfill mining	25.6	8.78
Partial excavation (2 m), refilling with clean soil, no enhanced landfill mining	24.8	5.79
Excavation, material recovery and Waste to Energy	35.3	12.1
Excavation and only material recovery	13.3	4.56

8. LFM project on a mono landfill containing fly ashes (Kluisbergen) – *analysis by Sweco Belgium*

8.1. Description and history of the site

The site used to be a former power plant fuelled by coal (**Figure 18**). It was built in 1958 and was the main and largest electrical and thermal plant of Belgium. The fuel for electricity production was mainly coal but also natural gas, wood waste and olive stone. The combustion of this fuel resulted in fly ash as waste product which was deposited on the site. The deposition area is estimated to be 82 000 m² with a thickness of 4.5m below the surface. This results in an estimated volume of 369 000 m³.

The plant was shut down in 2013 and was sold to private investors in 2014.

Figure 18: Aerial photograph of the landfill site area.

8.2. Drivers for the landfill mining project

In this case, the driver is the landfilled waste: fly ash. Reports on the analysis of the composition of the fly ash from 2015, show increased values of metals (mainly copper, chromium, zinc, lead, cadmium and nickel). There is an opportunity to sell the fly ashes as a building material. Hence, there is an economic driver, but also an environmental driver is present. Namely, the metals that are present, can leach out of the fly ash into groundwater layers, or by precipitation. This can create soil pollution. Therefore, recycling these metals could be beneficial for both economic and environmental reasons.

8.3. Stakeholder involvement

- OVAM: Supervising entity in waste management and soil remediation of Flanders
- owners of the terrain, initiator of the revalorization and redevelopment of the terrain
- The recognized remediation experts for the past soil investigations.

8.4. Characterization of the landfill content

In 2010, a a VLAREA certificate[2] was delivered, which indicated that the fly ashes can be used in building materials (e.g. cement, asphalt) according to their composition (fly ash produced by the combustion of 67% coal, 29.5% wood, 2.5% olive stone, 1% fuel oil).

In 2015, research was carried out on the stability and composition of the landfill by a cone penetration test (until +- 20 m below the surface) and drillings (until 4.5 m below the surface). Analysis certificates present increased values of metals (mainly copper, chromium, zinc, lead, cadmium and nickel).

8.5. Description of the landfill mining operations

These have not started yet.

8.6. Waste revalorization

The waste revalorization will be performed by excavating the fly ash deposition area. Afterwards, the excavated material can be transported to a specialized facility for metal extraction.

To evaluate whether mining of the landfill (not considered in the remediation plan) is a viable option, a scenario is worked out with ONTOL in the Budget section below.

8.7. Rehabilitation of the site

The goal of the rehabilitation is eliminating the potential ecotoxic risks and redeveloping the terrain as an industrial terrain for multiple companies.

8.8. Final results and benefits of the landfill mining project

The benefits of the landfill mining operations are both environmental and economic.

The main benefit is economic since the recycled metals, or the fly ashes in general, can be reused and have a monetary value. Also the rehabilitation of the site into an industrial terrain for multiple companies can provide working opportunities for in the region. The

[2] Certificate fort he use of secondary materials.

former power plant used to be the largest work facilitator for Kluisbergen. After this plant closed down, there has not been an employer like this ever since.

The environmental benefit will result from the excavation of the fly ashes which will reduce the potential spread of the pollution and also greatly reduce the ecotoxic risks for the region.

8.9. Laws and regulations applied

The legal constraints were dictated by the Bodemdecreet and the Vlaamse Codex voor Ruimtelijke Ordening (VCRO).

8.10. Budget

There are 2 possible option for which the budget can be estimated:

1. Processing the excavated materials as building materials;
2. Recycle the metals present in the fly ash.

8.10.1. Aggregates as building materials (ONTOL)

In **Figure 19**, the result of an ONTOL simulation is shown, where most of the excavated material is considered as aggregates for building materials (based on drilling logs, 2015). The largest cost in this whole process is for excavating and sorting, which are inevitable processes. The revenue created by selling the fly ash as building material, is based on an average which was included in the simulation. The price of land recovered is based on the average price of industrial land in Kluisbergen (82 euro/m^2).

The net present value of remediating the area of 82 000 m^2 and 369 000 m^3 would be estimated -€6 000 000. This is with a total cost of €16 700 000 and a revenue of €10 300 000 by selling excavated materials and selling the land. The environmental benefit, clean non-polluted soil in this area, can’t be forgotten and is also an invaluable asset. The recycling of metals as a pre-treatment step in this process, could be considered.

Final results

Description	Value	Unit
Net present value of costs	**-16.7**	**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	-11.0	Mio Euro
thermal utilization	0.0	Mio Euro
solid residues processing	-2.73	Mio Euro
landfill & disposal	-1.45	Mio Euro
transport	-1.5	Mio Euro
landscaping, env. supervision & overhead	-0.00426	Mio Euro
Net present value of avoided revenues	**0.0**	**Mio Euro**
Net present value of revenues	**10.3**	**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	6.11	Mio Euro
recovered land	4.18	Mio Euro
recovered landfill space	0.0	Mio Euro
used machinery	0.0	Mio Euro
Net present value of avoided costs	**0.422**	**Mio Euro**
Total net present value of the project (TNPV)	**-6.01**	**Mio Euro**
Specific net present value (SNPV)	**-16.3**	**Euro/Mg**

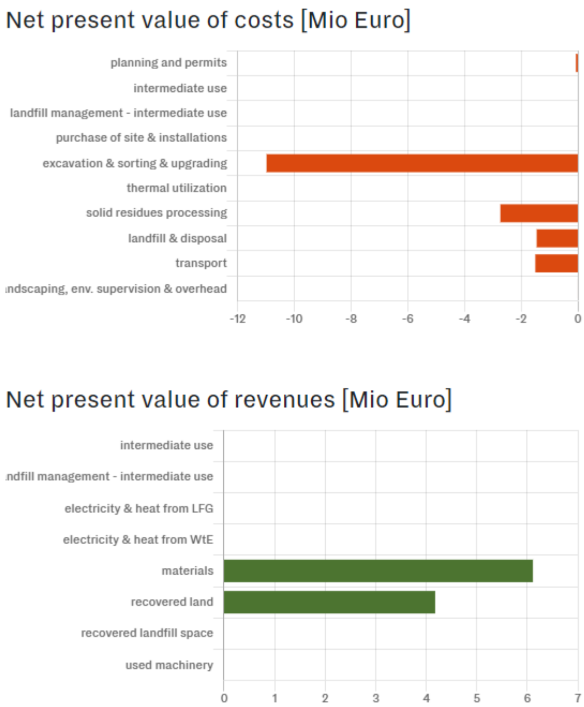


Figure 19: Results of the ONTOL model

8.10.2. Recycling metals

If the metals, present in the fly ashes, would be efficiently extracted. Then, considering the mass of 316 000 Mg excavated aggregates, the amount of metals extracted would result in the masses shown in **Table 5,** which are based on the lab results of MM1.

Table 5: Metal concentrations and total mass, based on the lab results of the soil analysis.

Metal	Concentration (mg/kg)	Total mass (kg)
Cadmium	1.2	379
Chromium	160	50560
Copper	110	37760
Nickel	100	31600
Lead	100	31600
Zinc	190	60040

If these metals could be extracted efficiently, an additional value can be generated.

8.10.3. Conclusion

If the revenue from extracted metals is included in the former simulation (where the revenue from materials as aggregates is now the revenue from materials as recycled metals) then there is roughly 5 000 000 EUR less revenue than when the entire excavated material is used as building material. Furthermore, the process of effectively extracting these metals should be considered in the calculations.

In conclusion, the best option within this budget simulation, is to use the excavated material as aggregates in building materials. Other options can be considered, as long as the redevelopment plan of the location is taken into account.

9. Rehabilitation of clay pits towards a mixed recreational and natural area (Rumst) – *analysis by Cornet & Renard*

9.1. Description of the site

The site is located just north of the town of Terhagen (Rumst) along the river Rupel between the E19 and A12 motorway, some 15 km south of the city of Antwerp. Three connected landfills are present at this site: a household waste landfill and two industrial landfills (asbestos waste and gypsum waste) (**Figure 20**). The landfills are created in former claypits. Currently, the site is a green area with large topographical differences due to partial backfilling of the former clay pits. Several parts are filled with water, forming different ponds in the area. The area is used by locals for recreational purposes (fishing, walking, playing, cycling, ...). According to the urban planning regulations, the area has a golf court destination.

Figure 20: Aerial photograph of the location of the landfill area

9.2. History of the site

From the end of the 19th century till the 1970s, the region was dominated by clay pits and brick factories along the river Rupel. During this period, clay was gradually excavated from the northern bank of the river Rupel towards the north. This created large pits that were

backfilled with overburden and wastes of different types.
Around 1971, a first landfill for industrial asbestos waste
from a local asbestos material producer was created in the northwestern corner of the area. Asbestos landfilling in this area continued till 1983. The waste consisted of testmaterial, onsold stock, broken pieces, flawd pieces, waste water sludge, …

In 1973, a landfill for shredded household waste from the city of Antwerp was created. This landfill was used untill 1983. In 1991 different claypits of the area were used to dump soil, dredged sludge and gypsum waste that were excavated during construction works of a nearby waterway. The gypsum waste was most likely dumbed as a soil-waste mixture.

In 2014, a descriptive soil investigation was performed in order to determine the need for remediation due to the presence of the different landfills and the potential impact on soil and groundwater quality, human health and the environment. The investigation concluded the following: *“Remediation is necessary because elevated ion concentrations from the leachate of the household waste can potentially impact the quality of the Rupel surface water. It is also necessary because exposed asbestos waste is present and the soil cover is contaminated with heavy metals. Both present a risk for human health.”*

9.3. Drivers for the landfill mining project

So far, no initiatives have been taken to assess the potential for a landfill mining project. The current project proposal aims at the valorisation of the land and its reclamation as a new green recreational area with different biotopes (ponds, marshes, slopes, meadows, …).

9.4. Stakeholder involvement

The owners of the landfill are The Flemish Governmental Agency for waterways and the Province of Antwerp are the owners of the site. There are also local action groups involved (named “Red onze kleiputten” or “save our clay pits”) that contest the remediation of the asbestos and household waste landfills. Many authorities are involved (local, regional) and several governmental agencies.

9.5. 5. Characterisation of the landfill content

Characteristics of the asbestos waste landfill:

- 43.000 m²
- 0,65 m thick
- 28.000 m³
- 50.000 ton
- Bound and free asbestos waste mixed with soil

Characteristics of the household waste landfill

- 100.000 m²

- 12 m thick
- 1.200.000 m³
- 1.800.000 ton
- Shredded household waste (unknown composition)

Characteristics of the gypsum waste landfill:

- 27.000 m²
- 2,6 m thick
- 70.000 m³ gypsum/soil mixture
- 120.000 ton

9.6. Description of the landfill mining operations

None so far

9.7. Waste revalorization

None so far

9.8. Rehabilitation of the site

The current plans are to provide a new isolating cover for the asbestos landfill and the household waste landfill and then raise the landfills and surrounding claypits by adding 2.300.000 m³ of external soil. A new green recreational area with different biotopes (ponds, marshes, slopes, meadows, …) will be created afterwards. A draft remedial project was developed. The estimated cost for this project is 5.300.000 euro. This includes the landfills and the surrounding former claypits. A draft of the planned rehabilitated area is shown in **Figure 21**.

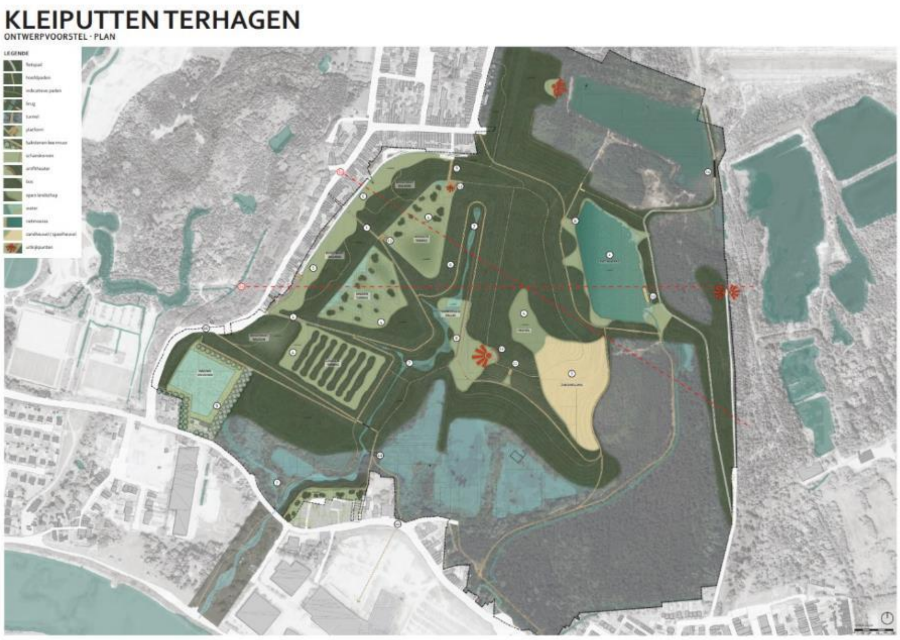


Figure 21: Draft of the landfill rehabilitation plan for the clay pits in Terhagen.

9.9. Final results and benefits of the landfill mining project

The current project proposal aims at the valorisation of the land and its reclamation as a new green recreational area with different biotopes (ponds, marshes, slopes, meadows, ...).

9.10. Laws and regulations applied

- Bodemdecreet (Soil remediation act)
- Decreet omgevingsvergunning (Environmental permitting act)
- Materialendecreet (Waste and materials act)
- Bosdecreet (Forest act)
- Decreet van 21 oktober 1997 betreffende het natuurbehoud en het natuurlijk milieu (Act regarding nature conservation and the natural environment)

9.11. Budget / Ontol-simulation

9.11.1. Asbestos landfill

There is no real mining goal for the asbestos landfill. The landfill does noy contain any recoverable materials. Therefore, the ONTOL scenario was based on a complete displacement of the landfill. Asbestos material requires a very specific treatment that depends on the percentage of asbestos and the fact that the asbestos is bounded or not. Each treatment for each specific form of asbestos waste has a cost that can differ significantly between treatment methodologies. The ONTOL model does not allow this distinction. It also does not incorporate specific costs related to toxic and hazardous waste removal and treatment. Therefore the outcome of the simulation is not considered realistic for the real removal of an asbestos landfill.

9.11.2. Household landfill

The scenario assesses a standard LFM approach where the landfill material is transported to the Antwerp Harbor area for separation and further material recovery/ treatment. The cut-off values for land price and metal price are respectively 1.390 €/m² and 4.090 €/ton. There are no economical perspectives that these values will ever be attained in the near or even distant future. Mining the household landfill due to its elevated thickness of 12 m does not seem economically feasible.

9.11.3. Gypsum landfill

Similar to the asbestos landfill, a LFM project for the gypsum landfill would signify the displacement of the material to a new landfill. There are no materials present in the waste material to be recovered. One would consider gypsum a non hazardous waste material that can be easily displaced. This is only partly true. Gypsum is a waste material from ore treatment and in this case, it is naturally enriched with radium and radon. Therefore disposal of this waste material also incorporates radiation and radon gas protective measures will be necessary. These specifics can not be modeled in the ONTOL model.

Therefore, the outcome of the model is not considered representative for the real displacement costs.

9.11.4. Conclusion

Overall, LFM is not considered to be socioeconomically viable for the case in Terhagen.

10. Rehabilitation of the landfill site to a new office park (Vilvoorde) – *analysis by Cornet & Renard*

10.1. Description of the site

The site is located in a larger industrial area east of the trainstation of the city of Vilvoorde. The site has a total area of approximately 30.000 m². The subject site only comprises a part of the total landfilled area. The total landfilled area continues towards the south and north of the subject site. The subject site is indicates in blue on the aerial photograph in **Figure 22**. The current spatial planning has designated the site for mixed commercial/industrial activities, more specifically a mix of services, food & drink, lodging, recreation, offices, socio-cultural and recreational activities. The following land uses are not allowed: housing, waste treatment, logistics and wholesale. Currently, the site comprises vacant land, two office buildings, roads and a parking.

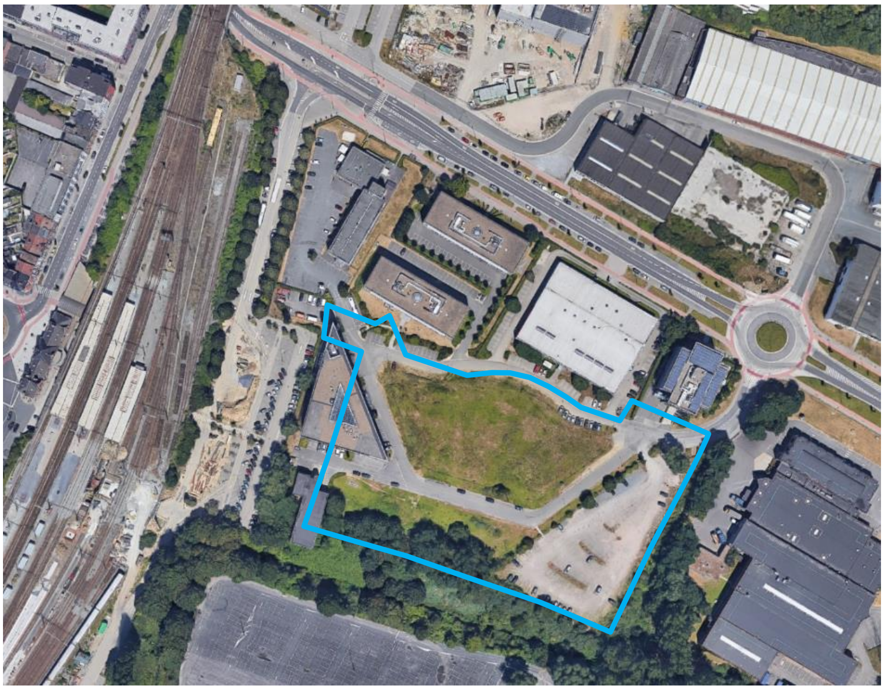


Figure 22: Aerial photograph of the landfill area.

10.2. History of the site

Before the 1950s, the site was agricultural land. In 1951, the first landfill activities started in the east of the site. In 1954, an official permit was provided by the municipality to use the subject site as a horse cemetery. In the following years, the site was used for the disposal of household waste. The aerial photograph of 1971 shows the ongoing landfill activities at the site (**Figure 23**). In the 1980s, the landfill was covered and partly used as a grazing pasture. Between 1983 and 1991, a scrap yard as present at the site. From the beginning of the 1990s, the site was redeveloped and office building and roads were constructed.

Figure 23: Aerial photograph (1971) where the landfill activities are present

In 2017, a descriptive soil investigation was performed in order to determine the need for remediation due to the presence of the landfill and the potential impact on soil and groundwater quality, human health and the environment. The investigation concluded the following: *"Remediation is necessary because of a potential risk for future use from vapour inhalation for people on site, 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 fill material is directly in contact with the groundwater. The groundwater of the subject site an the adjacent former landfills is contaminated."*

10.3. Drivers for the landfill mining project

So far, no initiatives have been taken to assess the potential for a landfill mining project. The site is located in an urban area next to the city centre of Vilvoorde and adjacent to the train station with relatively good connections to Brussels and the E19 highway, making the site an interesting investment for redevelopment.

10.4. Stakeholder involvement

The owner of the site will be involved, as well as the user of the office buildings on the site. Different authorities are involved (OVAM, the Province, Flemish Government and the municipality of Vilvoorde).

10.5. Characterisation of the landfill content

The landfill contains household waste that is covered by approximately 1,5 m of clean soil. The landfill has the following characteristics:

- 45.000 m²
- 4 m thick (1,5 – 5,5 m below ground level)
- 180.000 m³
- 310.000 ton
- Waste types: soil, wood, bricks, household waste, industrial waste, … (unknown composition, **Figure 24**)

Figure 24: Pictures of the waste material present in the landfill

10.6. Description of the landfill mining operations

None so far.

10.7. Waste revalorization

None so far.

10.8. Rehabilitation of the site

The current plans are to redevelop the site as an office park with more than 30.000 m² of office space, 2.600 m² of green spaces, 700 car park spaces and 400 bicycle spaces.

A draft of the planned rehabilitated area is presented in **Figure 25**.

Figure 25: rehabilitation plan for the landfill site

10.9. Final results and benefits of the landfill mining project

The current project proposal aims at the valorisation of the land and its reclamation as an office park with more than 30.000 m² of office space, 2.600 m² of green spaces, 700 car park spaces and 400 bicycle spaces.

10.10. Laws and regulations applied

- Bodemdecreet (Soil remediation act)
- Decreet omgevingsvergunning (Environmental permitting act)
- Materialendecreet (Waste and materials act)

10.11. Budget / Ontol-simulations

10.11.1. Household landfill

In this scenario, the whole household landfill is mined. All material is excavated and transported to the Antwerp harbour region for processing. After mining, the site is reused as industrial land. There is profit from land sale. The LFM project would reduce overall GHG emissions compared to a 'do nothing' scenario by reusing some landfill material as fuel. The applied land price of 280 €/m² needs to be more than double or the overall average metal valorization price of 470 €/ton needs to be almost triple to make the project economically viable.

10.11.2. Reduced landfill

In this scenario, the same area as in the previous scenario 'household landfill' is mined, but a less conservative waste volume is considered. For this evaluation the volume is reduced by 40% to 108.000 m³ and 190.000 ton. Again, the removal of waste provides an environmental gain as less GHG are emitted into the environment when the waste material can partly be reused as a substitute fuel.

This scenario provides a more socioeconomically viable project. However, it remains not profitable as the costs still exceed the potential profit. To cover all costs, the land price value needs to increase by more than 30% or the metal valorization price needs to double. Both are considered unlikely taking into account the current social and economical climate.

Overall it seems that no viable LFM project is feasible for this site.

10.11.3. Conclusion

Overall it seems that no viable LFM project is feasible for this site.

11. Industrial development after landfill remediation (Puurs) – *analysis by Cornet & Renard*

11.1. Description of the site

The site is located across the A12 highway (Brussels-Antwerp) and adjacent to the canal Brussels-Scheldt river. Until the 1980,s the area was wet agricultural land. In 1983, a nearby located company obtained a permit to use the site to landfill dewatered gypsum waste. The gypsum waste was stored without any protective measures on the pristine soil. The gypsum was piled up to a total height of approximately 15 m above the adjacent land and finally covered by a layer composed of soils from different unknown origins. Since the end of the landfilling activities in 1987, the site was closed and was not used since.

In the last decade, the most south-eastern edge of the landfill has been redeveloped to create a new exit for the A12 highway (**Figure 26**). In the same period, 2 windmills were installed on the landfill.

In February 2019, a new spatial implementation plan for the area was approved in which the landfill site got a new development as industrial land.

Figure 26: Aerial photograph of the landfill site area

11.2. History of the site

In the beginning of 1983, the first landfilling activities started at the southern part of the site. The current gypsum waste storage was completed 4 years later in 1987.

After the gypsum waste was sufficiently compacted the landfill was covered with residual soil from nearby construction works. The quality of these soils was never tested as there was no legal obligation in those days (specific legalisation from 2004) . The soil investigations undertaken in the early 2000s have shown that the composition of this cover layer is quite heterogeneous. The thickness of this layer varies between 30 cm and 1 m. After completion of the cover layer grass like vegetation was sown in and bushes and shrubs were planted in on the slopes.

Between 2004 and 2009, a descriptive soil investigation was performed in order to determine the need for remediation. The investigation concluded that there was no risk for the land use at that time (vacant land, occasionally used for maintenance purposes). In the future, these conditions will no longer be valid as the site will be redeveloped.

11.3. Drivers for the landfill mining project

So far, no initiatives have been taken to assess the potential for a landfill mining project. The current project proposal aims at the valorization of the land and its reclamation as an industrial and logistical site.

11.4. Stakeholder involvement

The landowner is a private company and took the initiative to set up a redevelopment project on this landfill site. A project proposal was introduced at the Flemish government in order to obtain a brownfield covenant. During this procedure stakeholder involvement was organized at several levels (regional, provincial, local). Different aspects such as spatial planning, mobility and transport, environmental impact and sustainability were discussed during the negotiations of this brownfields project. Also public communication and consultation was set up.

More information :

- https://www.interregeurope.eu/policylearning/good-practices/item/2966/brownfieldcovenants-as-an-instrument-to-revitalize-former-landfill-sites/
- https://www.youtube.com/watch?v=b3ukwTjEcXM&list=PL0K_n6Q0D44AgWHVMUIEh34SfTHgpyIxF&index=9
- https://www.youtube.com/watch?app=desktop&v=Rhg9Gt6xJQw&list=PL0K_n6Q0D44AgWHVMUIEh34SfTHgpyIxF&index=10

11.5. Characterisation of the landfill content

Characteristics of the industrial gypsum waste landfill:

- 135.000 m²
- Average 15 m thick
- 2.025.000 m³
- 3.500.000 ton
- Industrial gypsum waste
- The waste contains elevated radium and radon concentrations (elevated radiation levels)

11.6. Description of the landfill mining operations

None so far.

11.7. Waste revalorization

None so far.

11.8. Rehabilitation of the site

Currently plans are being drafted to redevelop the landfill in to an industrial area with warehouses, small business units and offices. The plan intends to not alter the overall shape of the landfill. Only minor alterations are foreseen.

Specific construction measures are foreseen to prevent radon gas accumulation in the planned buildings.

11.9. Final results and benefits of the landfill mining project

The current project proposal aims at the valorisation of the land and its reclamation as an industrial area with warehouses, small business units and offices.

11.10. Laws and regulations applied

- Bodemdecreet (Soil remediation act)
- Decreet omgevingsvergunning (Environmental permitting act)
- Materialendecreet (Waste and materials act)

11.11. Budget / Ontol-simulation

A LFM project for the gypsum waste landfill would signify the displacement of the material to a new landfill, because there is no recoverable material present. One would consider gypsum a non hazardous waste material that can be easily displaced. This is only partly true. Namely, gypsum is a waste material from ore treatment that is naturally enriched with radium and radon. Therefore, disposal of this waste material also includes radiation

and radon gas protective measures will be necessary.
These specifics can not be modeled in the ONTOL model.

In this scenario, a worst case approach was applied where the gypsum material is considered hazardous waste that needs to be displaced to a new landfill. The dumping cost at this new facility drives the total project cost to almost 10 million euros (see Appendix). The project is not economically viable.

12. Improving water storage by consolidating 4 closely located landfills (Heist-op-den-Berg) – *analysis by Cornet & Renard*

12.1. Description of the site

This case study concerns an area where several small landfills are located around the river Grote Nete (**Figure 27**). The area comprises 4 landfills of which 2 have been the subject of a site investigation (C and D). According to the available information, the four landfills can be described as follows:

- Landfill A: a former municipal landfill for inert material;
- Landfill B: a former household waste landfill;
- Landfill C: a former permitted household waste landfill;
- Landfill D: a former illegal general waste landfill.

The landfill sites are situated in a nature area in the valley of the Grote Nete river. All sites are or used as pasture or are vacant green land.

Figure 27: Aerial photograph of the 4 landfills located in the Grote Nete river valley

12.2. History of the site

It is unclear when the first landfilling activities started. According to the permit of landfill C, it was used from 1974 till 1978. Most likely, the landfilling at the three other sites did also take place during the 1970s and potentially also during the 1980s. As the waste material was dumbed directly in the former marshes, the thickness of most of the landfill material is limited. There is no further available information on the history of the landfills.

12.3. Drivers for the landfill mining project

So far, no initiatives have been taken to assess the potential for a landfill mining project.

12.4. Stakeholder involvement

The owners of the landfill are mainly private actors. Also one of the parcels in owned by the municipality. Different authorities are involved (OVAM, the Province, Flemish Government and the municipality of Heist-op-den-Berg).

12.5. Characterisation of the landfill content

- Landfill A:
  - 13.500 m²
  - thickness: unknown --> assumed 2 m
  - 27.000 m³
  - 48.000 ton
  - Inert waste

- Landfill B:
  - 2.500 m²
  - thickness: unknown: assumed 2 m
  - 5.000 m³
  - 9.000 ton
  - household waste

- Landfill C:
  - 11.400 m²
  - approx. 1,5 m
  - 17.100 m³
  - 31.000 ton
  - household waste

- Landfill D:
  - 7.800 m²
  - approx. 2 m
  - 15.600 m³
  - 27.000 ton
  - general waste

12.6. Description of the landfill mining operations

None so far.

12.7. Waste revalorization

None so far.

12.8. Rehabilitation of the site

A landfill mining project for the 4 landfills could be beneficial for the natural value of the area. Furthermore, the landfills are located in the valley of the Grote Nete river. A landfill mining project could contribute to a better water storage or water management in the area.

12.9. Final results and benefits of the landfill mining project

The current project proposal aims at the valorisation of the land and its reclamation as a natural area with a high capacity for water storage and management.

12.10. Laws and regulations applied

- Bodemdecreet (Soil remediation act)
- Decreet omgevingsvergunning (Environmental permitting act)
- Materialendecreet (Waste and materials act)

12.11. 11. Budget / Ontol-simulations

The 4 landfills are modelled as one combined landfill with a total surface of 35.200 m², an average thickness of 1,84 m, a total volume of 64.700 m³ and a mass of 115.000 ton. 2 scenario's are considered:

1. The 4 landfills are mined
2. The three landfills A, B en D are excavated and consolidated at landfill C to reduce the overall landfill footprint.

12.11.1. Scenario 1

All material is excavated and transported to the Antwerp harbour region for processing. After mining, the sites are reused as green land (nature). There is no profit from land sale. The LFM project would reduce overall GHG emissions compared to a 'do nothing' scenario by reusing some landfill material as fuel.

The overall costs of the LFM project can't be covered by the profit that can be made from either the reuse of the materials present and the value of the reusable land (20 €/ton). The profit becomes economically feasible if the reclaimed land value would increase to a value of >140 €/ton (or approx. 460 €/m³) or if the value of the reclaimed materials would increase by over 300%. Both do not seem very likely considering the designated land use (nature) and relatively stable raw material prices.

12.11.2. Scenario 2

The current version of ONTOL does not allow to directly model a consolidation scenario. Hence, a work around was used where a new landfill was created, representing landfill C, where all excavated waste is directly deposited and basically no material is mined. To allow this scenario, the excavated waste material was defined as 99,99% stones & inerts.

Consolidation provides an environmental gain as the model assumes that the newly created landfill will collect and use any GHG from the waste, while this is not the case when the landfills remain in place.

The model uses a default land value of 20 €/ton for reclaimed land. This is much higher than the general price for nature land. The model indicates that the redeposition scenario is at breakeven at a land value of 26 €/ton.

Overall, this scenario is considered more socioeconomically viable than the full LFM scenario.

13. LFM project with recreational redevelopment (Kruibeke) – *analysis by Tauw Belgium*

13.1. Description of the site

The site is located in Kruibeke and is currently owned by the municipality of Kruibeke. The landfill has an area of approximately 10 000 m². The research location is located in a natural area and is surrounded by grasslands on the north and east (**Figure 28**). In the south of the site, allotment gardens are present, used by the inhabitants in the neighbourhood. The ground level of the allotments is approx. 0.5 - 1.0 m lower than the surrounding area.

Figure 28: Aerial photograph of the landfill site area.

13.2. History of the site

The landfill can be divided in two zones, based on the period of activity and the a-waste composition:

- The western part (1655 m²): landfill period before 1960;
- The eastern part (7894 m²): landfill period between 1960-1980.

No further information is available on the history of this landfill.

Currently, the western part of the landfill is used by a farmer as storage for animal feed. This animal feed is covered by a layer of approximately 0.5 m of bulk material.

The eastern and bigger part of the landfill, has been completely occupied as a landfill site. The location is densely vegetated and not used at the moment.

13.3. Drivers for the landfill mining project

As the site is currently not used, it would be beneficial for the area and the neighbourhood to excavate the waste materials. In that way, the site could be redeveloped as nature and/or recreational area. For example, the gardan allotments could be expanded or combined with a playground. The increased natural value created by this project and the safer living environment for humans and animals are the most important drivers to carry out the project.

13.4. Stakeholder involvement

The municipality can be seen as the most important stakeholder, as well as the owner of the property. Furthermore, the owner of the asjacent farmland and the local youth movement should be involved. Namely, the local youth movement , because they have plans to built a new youth centre. The latter will be included in the spatial planning design for the neighbourhood, which is currently set on-hold.

13.5. Characterization of the landfill content

No soil investigations have been carried out at the site, so no specific information on the content of the landfill is available.

For the allotments on the adjacent parcel, some soil samples of the top layer were analysed in 2014, on the initiative of the municipality and the province. In these soil samples, increased levels of Cd (> 2,000 mg/kg ds) were measured and pH values for cultivation seemed to be too low. A sorting test was performed by VITO, with the following conclusions per fraction:

- Fraction < 10 mm:

The fraction < 4 mm mainly consists of normal soil material. The larger fraction, 4-10 mm, consists of small pebbles and particles of asphalt. Hence, the quality of this < 10 mm fraction could be ameliorated by sieving out the >4 mm fraction. In that way, the contamination with PAH’s would be reduced. This would result in a difference of 500 ton.

- Fraction > 10 mm, < 100 mm;

This fraction consists of demolition waste, with a percentage asphalt of approximately 35%, resulting in a contamination with PAH's and mineral oil. This concerns 6400 ton of material. The costs for separation of this material are estimated at 1 million euro.

- Fraction > 100 mm;

In this fraction and in the landfill, a specific layer of roof-bitumen was identified. (11%). This layer could be selectivey removed during the excavation. This approach could favour the valorisation potential of this material as recycles granulates. Also cobblestones are present, which can be revalorized as well. Together, the valorisation of these materials would result in a cost of 90 000 euro, when they are incorporated in the redevelopment project after the waste excavation.

13.6. Description of the landfill mining operations

The redevelopment could consist of the following steps:

1. The vegetation must be removed
2. The site must be excavated to a depth of approximately 2 m-mv, all material must be sifted and sorted.
3. After supplementing with backfill soil to the original ground level, the site can be redeveloped into a natural or recreational area.

13.7. Waste revalorization

For the valorisation of the landfill material, the sorting study of VITO (2015) was used. The costs for the separate removal and processing of the landfill material are estimated at 1.000.000 to 1.200.000 euro. This does not take into account the possibility to process bulk materials locally after separating and sorting as backfilling soil (for the soil fraction) or building material (eg. stone rubble as sub-foundations).

13.8. Rehabilitation of the site

The purpose of the redevelopment of this site is to upgrade it into a recreational and/or natural area.

The study by VITO (2015) also procided estimations for the valorsation of the site as built-up area. In that case, the eventual value of the land after removal of the landfill would be 200 euros/m². For a landfill area of approximately 4000 m², this results in a value of 800.000 euros. The unit price for a recreation area is 25 to 60 euros/m². For a landfill area of approx. 4000 m², this therefore comes down to a value of 100,000 to 240,000 euros.

13.9. Final results and benefits of the landfill mining project

The current project proposal aims at the valorisation of the land and its reclamation as a natural or recreational area.

13.10. Laws and regulations applied

The disposal of the landfill and the reuse of certain fractions must take place on account taking into account, among other things, the Soil Decree, the Vlarebo and the Vlarema.

13.11. Budget

Budget estimations were already included in the previous sections.

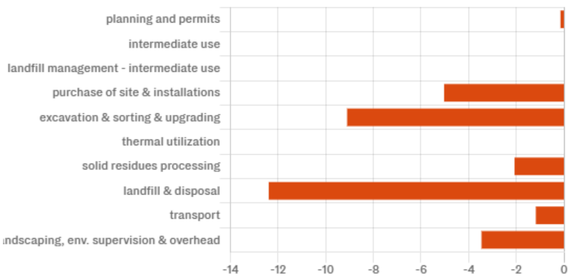
APPENDIX

1.1.1. 6No material recycling, no waste to energy, no landfill gas to energy

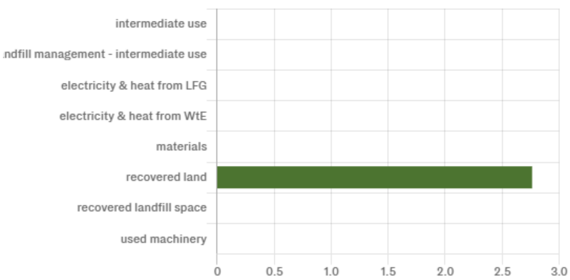
Final results

Description	Value	Unit
Net present value of costs	**-33.4**	**Mio Euro**
planning and permits	-0.142	Mio Euro
intermediate use	0.0	Mio Euro
landfill management - intermediate use	0.0	Mio Euro
purchase of site & installations	-5.03	Mio Euro
excavation & sorting & upgrading	-9.1	Mio Euro
thermal utilization	0.0	Mio Euro
solid residues processing	-2.07	Mio Euro
landfill & disposal	-12.4	Mio Euro
transport	-1.18	Mio Euro
landscaping, env. supervision & overhead	-3.46	Mio Euro
Net present value of avoided revenues	**0.0**	**Mio Euro**
Net present value of revenues	**2.76**	**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	3.33e-06	Mio Euro
recovered land	2.76	Mio Euro
recovered landfill space	0.0	Mio Euro
used machinery	0.0	Mio Euro
Net present value of avoided costs	**2.36**	**Mio Euro**
Total net present value of the project (TNPV)	**-28.3**	**Mio Euro**
Specific net present value (SNPV)	**-92.3**	**Euro/Mg**

Net present value of costs [Mio Euro]



Net present value of revenues [Mio Euro]

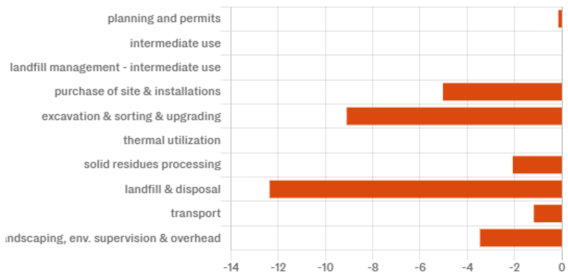


1.1.2. 6No waste to energy, no landfill gas to energy, only material recycling

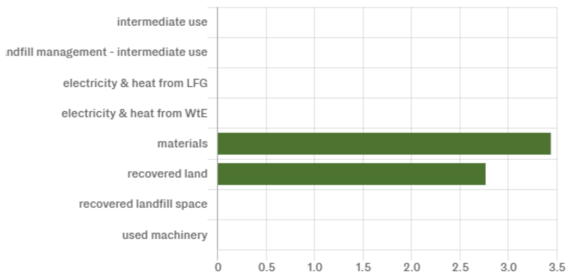
Final results

Description	Value	Unit
Net present value of costs	**-33.3**	**Mio Euro**
planning and permits	-0.142	Mio Euro
intermediate use	0.0	Mio Euro
landfill management - intermediate use	0.0	Mio Euro
purchase of site & installations	-5.03	Mio Euro
excavation & sorting & upgrading	-9.1	Mio Euro
thermal utilization	0.0	Mio Euro
solid residues processing	-2.07	Mio Euro
landfill & disposal	-12.4	Mio Euro
transport	-1.18	Mio Euro
landscaping, env. supervision & overhead	-3.46	Mio Euro
Net present value of avoided revenues	**0.0**	**Mio Euro**
Net present value of revenues	**6.2**	**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	3.44	Mio Euro
recovered land	2.76	Mio Euro
recovered landfill space	0.0	Mio Euro
used machinery	0.0	Mio Euro
Net present value of avoided costs	**2.36**	**Mio Euro**
Total net present value of the project (TNPV)	**-24.8**	**Mio Euro**
Specific net present value (SNPV)	**-81.0**	**Euro/Mg**

Net present value of costs [Mio Euro]



Net present value of revenues [Mio Euro]

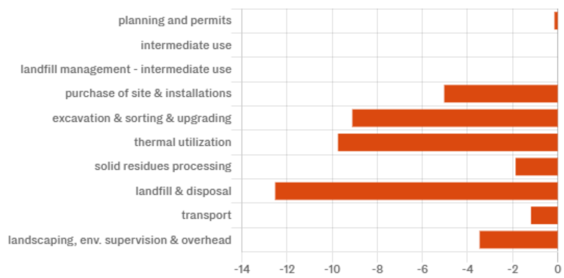


1.1.3. 6No landfill gas to energy, only material recycling and waste to energy

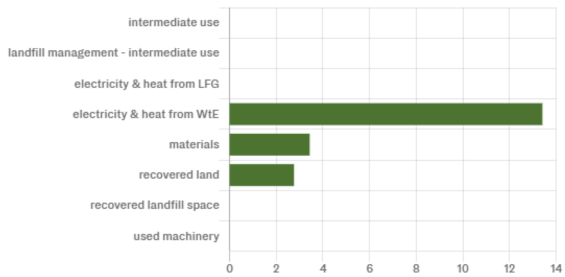
Final results

Description	Value	Unit
Net present value of costs	**-43.0**	**Mio Euro**
planning and permits	-0.142	Mio Euro
intermediate use	0.0	Mio Euro
landfill management - intermediate use	0.0	Mio Euro
purchase of site & installations	-5.03	Mio Euro
excavation & sorting & upgrading	-9.1	Mio Euro
thermal utilization	-9.74	Mio Euro
solid residues processing	-1.86	Mio Euro
landfill & disposal	-12.5	Mio Euro
transport	-1.18	Mio Euro
landscaping, env. supervision & overhead	-3.46	Mio Euro
Net present value of avoided revenues	**0.0**	**Mio Euro**
Net present value of revenues	**19.6**	**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	13.4	Mio Euro
materials	3.44	Mio Euro
recovered land	2.76	Mio Euro
recovered landfill space	0.0	Mio Euro
used machinery	0.0	Mio Euro
Net present value of avoided costs	**2.36**	**Mio Euro**
Total net present value of the project (TNPV)	**-21.1**	**Mio Euro**
Specific net present value (SNPV)	**-68.9**	**Euro/Mg**

Net present value of costs [Mio Euro]



Net present value of revenues [Mio Euro]

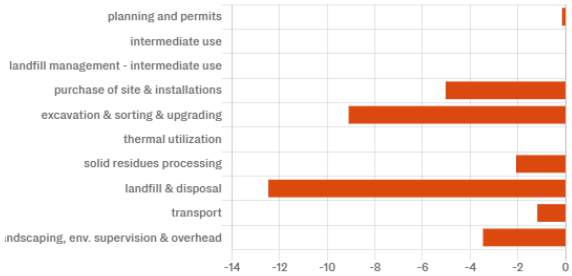


1.1.4. 6No waste to energy, only material recycling and landfill gas to energy

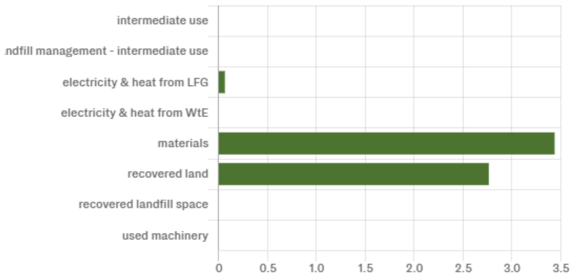
Final results

Description	Value	Unit
Net present value of costs	**-33.5**	**Mio Euro**
planning and permits	-0.142	Mio Euro
intermediate use	0.0	Mio Euro
landfill management - intermediate use	0.0	Mio Euro
purchase of site & installations	-5.03	Mio Euro
excavation & sorting & upgrading	-9.1	Mio Euro
thermal utilization	0.0	Mio Euro
solid residues processing	-2.07	Mio Euro
landfill & disposal	-12.5	Mio Euro
transport	-1.18	Mio Euro
landscaping, env. supervision & overhead	-3.46	Mio Euro
Net present value of avoided revenues	**-0.463**	**Mio Euro**
Net present value of revenues	**6.26**	**Mio Euro**
intermediate use	0.0	Mio Euro
landfill management - intermediate use	0.0	Mio Euro
electricity & heat from LFG	0.062	Mio Euro
electricity & heat from WtE	0.0	Mio Euro
materials	3.44	Mio Euro
recovered land	2.76	Mio Euro
recovered landfill space	0.0	Mio Euro
used machinery	0.0	Mio Euro
Net present value of avoided costs	**2.47**	**Mio Euro**
Total net present value of the project (TNPV)	**-25.2**	**Mio Euro**
Specific net present value (SNPV)	**-82.3**	**Euro/Mg**

Net present value of costs [Mio Euro]



Net present value of revenues [Mio Euro]

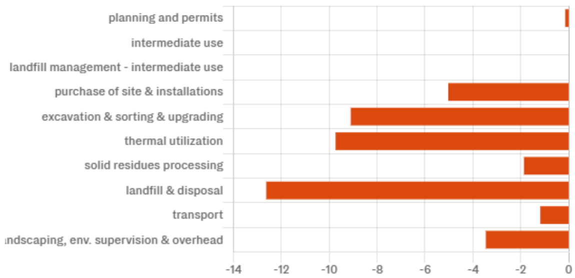


1.1.5. 6Material recycling, waste to energy and landfill gas to energy

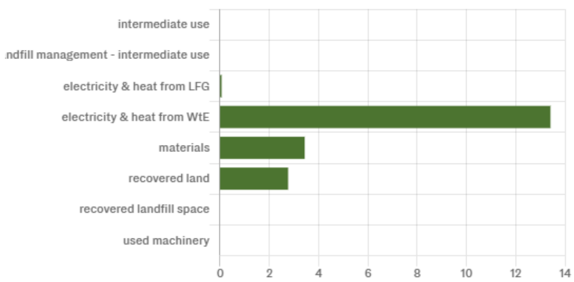
Final results

Description	Value	Unit
Net present value of costs	**-43.2**	**Mio Euro**
planning and permits	-0.142	Mio Euro
intermediate use	0.0	Mio Euro
landfill management - intermediate use	0.0	Mio Euro
purchase of site & installations	-5.03	Mio Euro
excavation & sorting & upgrading	-9.1	Mio Euro
thermal utilization	-9.74	Mio Euro
solid residues processing	-1.86	Mio Euro
landfill & disposal	-12.6	Mio Euro
transport	-1.18	Mio Euro
landscaping, env. supervision & overhead	-3.46	Mio Euro
Net present value of avoided revenues	**-0.463**	**Mio Euro**
Net present value of revenues	**19.7**	**Mio Euro**
intermediate use	0.0	Mio Euro
landfill management - intermediate use	0.0	Mio Euro
electricity & heat from LFG	0.062	Mio Euro
electricity & heat from WtE	13.4	Mio Euro
materials	3.44	Mio Euro
recovered land	2.76	Mio Euro
recovered landfill space	0.0	Mio Euro
used machinery	0.0	Mio Euro
Net present value of avoided costs	**2.47**	**Mio Euro**
Total net present value of the project (TNPV)	**-21.5**	**Mio Euro**
Specific net present value (SNPV)	**-70.2**	**Euro/Mg**

Net present value of costs [Mio Euro]



Net present value of revenues [Mio Euro]

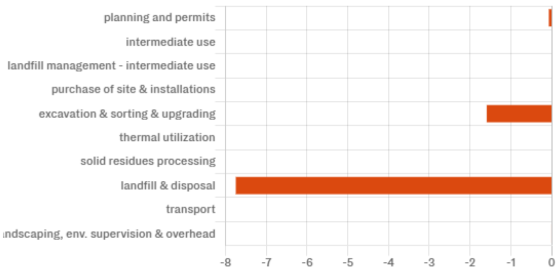


1.1.1. 7Excavation of the whole landfill, refilling with clean soil, no enhanced landfill mining

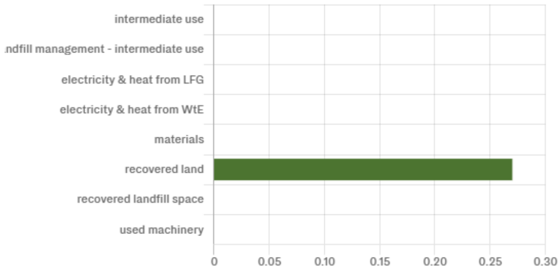
Final results

Description	Value	Unit
Net present value of costs	**-9.41**	**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	-1.59	Mio Euro
thermal utilization	0.0	Mio Euro
solid residues processing	0.0	Mio Euro
landfill & disposal	-7.75	Mio Euro
transport	0.0	Mio Euro
landscaping, env. supervision & overhead	-0.00426	Mio Euro
Net present value of avoided revenues	**0.0**	**Mio Euro**
Net present value of revenues	**0.27**	**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	0.0	Mio Euro
recovered land	0.27	Mio Euro
recovered landfill space	0.0	Mio Euro
used machinery	0.0	Mio Euro
Net present value of avoided costs	**0.354**	**Mio Euro**
Total net present value of the project (TNPV)	**-8.78**	**Mio Euro**
Specific net present value (SNPV)	**-25.6**	**Euro/Mg**

Net present value of costs [Mio Euro]



Net present value of revenues [Mio Euro]

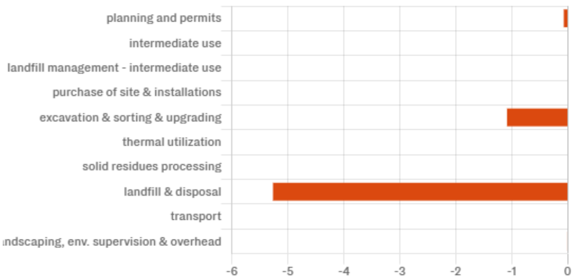


1.1.2. 7Partial excavation (2 m), refilling with clean soil, no enhanced landfill mining

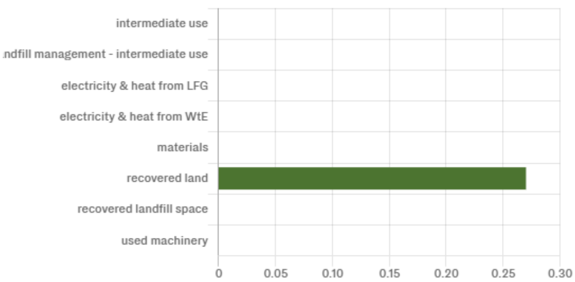
Final results

Description	Value	Unit
Net present value of costs	**-6.41**	**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	-1.08	Mio Euro
thermal utilization	0.0	Mio Euro
solid residues processing	0.0	Mio Euro
landfill & disposal	-5.26	Mio Euro
transport	0.0	Mio Euro
landscaping, env. supervision & overhead	-0.00426	Mio Euro
Net present value of avoided revenues	**0.0**	**Mio Euro**
Net present value of revenues	**0.27**	**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	0.0	Mio Euro
recovered land	0.27	Mio Euro
recovered landfill space	0.0	Mio Euro
used machinery	0.0	Mio Euro
Net present value of avoided costs	**0.354**	**Mio Euro**
Total net present value of the project (TNPV)	**-5.79**	**Mio Euro**
Specific net present value (SNPV)	**-24.8**	**Euro/Mg**

Net present value of costs [Mio Euro]



Net present value of revenues [Mio Euro]

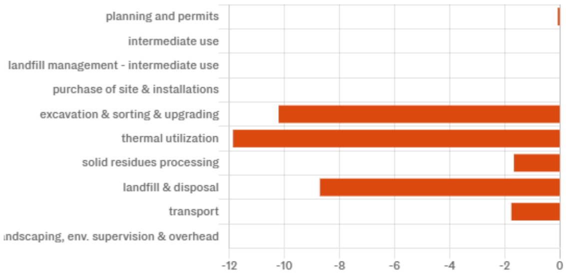


1.1.3. 7Excavation, material recovery and Waste to Energy

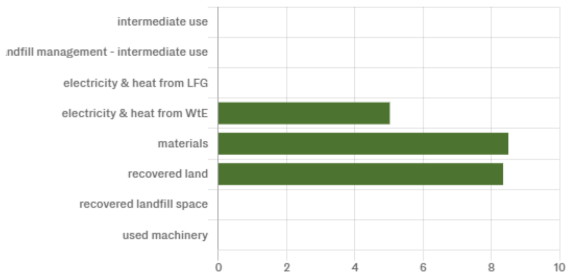
Final results

Description	Value	Unit
Net present value of costs	**-34.2**	**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	-10.2	Mio Euro
thermal utilization	-11.9	Mio Euro
solid residues processing	-1.66	Mio Euro
landfill & disposal	-8.7	Mio Euro
transport	-1.75	Mio Euro
landscaping, env. supervision & overhead	-0.00426	Mio Euro
Net present value of avoided revenues	**-0.721**	**Mio Euro**
Net present value of revenues	**21.9**	**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	5.03	Mio Euro
materials	8.5	Mio Euro
recovered land	8.35	Mio Euro
recovered landfill space	0.0	Mio Euro
used machinery	0.0	Mio Euro
Net present value of avoided costs	**0.98**	**Mio Euro**
Total net present value of the project (TNPV)	**-12.1**	**Mio Euro**
Specific net present value (SNPV)	**-35.3**	**Euro/Mg**

Net present value of costs [Mio Euro]



Net present value of revenues [Mio Euro]

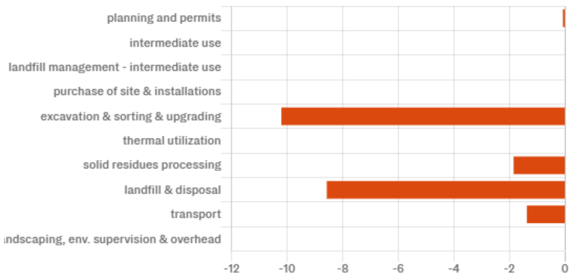


1.1.4. 7Excavation and only material recovery

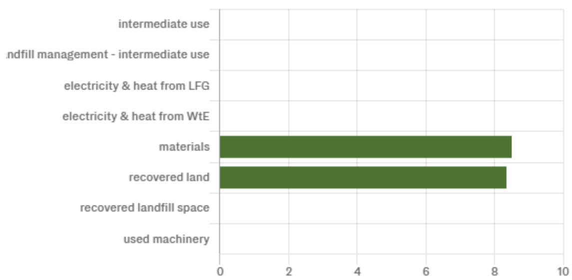
Final results

Description	Value	Unit
Net present value of costs	**-22.0**	**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	-10.2	Mio Euro
thermal utilization	0.0	Mio Euro
solid residues processing	-1.84	Mio Euro
landfill & disposal	-8.57	Mio Euro
transport	-1.36	Mio Euro
landscaping, env. supervision & overhead	-0.00426	Mio Euro
Net present value of avoided revenues	**0.0**	**Mio Euro**
Net present value of revenues	**16.9**	**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	8.5	Mio Euro
recovered land	8.35	Mio Euro
recovered landfill space	0.0	Mio Euro
used machinery	0.0	Mio Euro
Net present value of avoided costs	**0.63**	**Mio Euro**
Total net present value of the project (TNPV)	**-4.56**	**Mio Euro**
Specific net present value (SNPV)	**-13.3**	**Euro/Mg**

Net present value of costs [Mio Euro]



Net present value of revenues [Mio Euro]



ID	Description	Flow Mg/yr	Mg
Excavation, Sorting and Upgrading			
EW1	Excavated waste	36,900	369,000
RDW	Residues (internally re-deposited) (total)	0	0
FMr	Residues (to external landfill) (total)	1,845	18,452
FM1	Ferrous metals (total)	0	3
NFM1	Non-ferrous metals (total)	0	6
Ro	Plastics to recycling (total)	0	0
HM	Hazardous materials (total)	738	7,383
ACM	Aggregates (total)	31,604	316,049
Waste Incineration			
CCM	Combustible materials (total)	2,710	27,104
FG	Off gas	947	9,479
SR	Solid residues (bottom ash, fly ash and APC residues)	1,762	17,625
AtL	Bottom ash to landfill	1,762	17,625
FA	Fly ash and APC residues	0	0
FM2	Fe scrap recovered	0	0
NFM2	NFe scrap recovered	0	0
RtR	Aggregates (derived from bottom ash) to recycling	0	0
Material Recycling			
FMt	Ferrous metals (total)	0	3
Cut	Copper (total)	0	3
Alt	Aluminium (total)	0	3
CM	Construction materials (aggregates)	31,604	316,049
Rcb	Plastics to recycling (total)	0	0

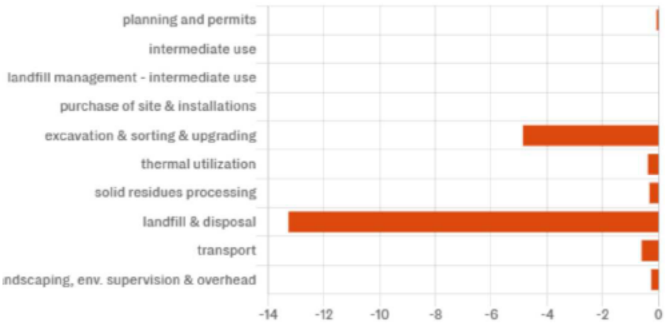
8

9 asbestos

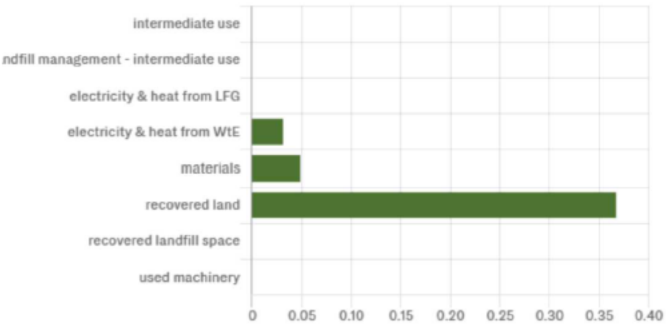
Final results

Description	Value	Unit
Net present value of costs	**-19.7**	**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	-4.86	Mio Euro
thermal utilization	-0.373	Mio Euro
solid residues processing	-0.321	Mio Euro
landfill & disposal	-13.3	Mio Euro
transport	-0.601	Mio Euro
landscaping, env. supervision & overhead	-0.246	Mio Euro
Net present value of avoided revenues	**0.0**	**Mio Euro**
Net present value of revenues	**0.447**	**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	0.031	Mio Euro
materials	0.0484	Mio Euro
recovered land	0.367	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)	**-19.3**	**Mio Euro**
Specific net present value (SNPV)	**-161.0**	**Euro/Mg**

Net present value of costs [Mio Euro]



Net present value of revenues [Mio Euro]

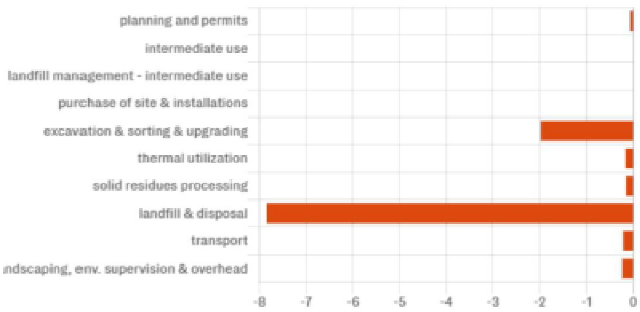


9 gypsum

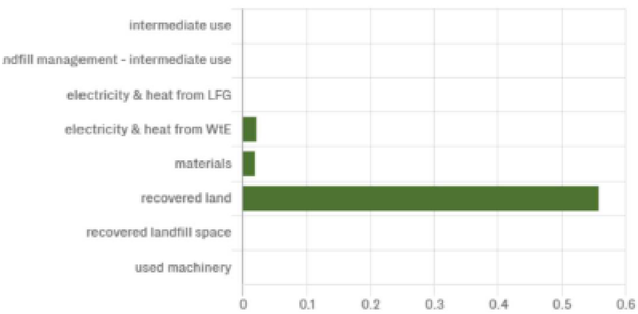
Final results

Description	Value	Unit
Net present value of costs	-10.6	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	-1.98	Mio Euro
thermal utilization	-0.16	Mio Euro
solid residues processing	-0.147	Mio Euro
landfill & disposal	-7.84	Mio Euro
transport	-0.219	Mio Euro
landscaping, env. supervision & overhead	-0.234	Mio Euro
Net present value of avoided revenues	0.0	Mio Euro
Net present value of revenues	0.597	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	0.0207	Mio Euro
materials	0.0186	Mio Euro
recovered land	0.557	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)	-10.0	Mio Euro
Specific net present value (SNPV)	-201.0	Euro/Mg

Net present value of costs [Mio Euro]



Net present value of revenues [Mio Euro]

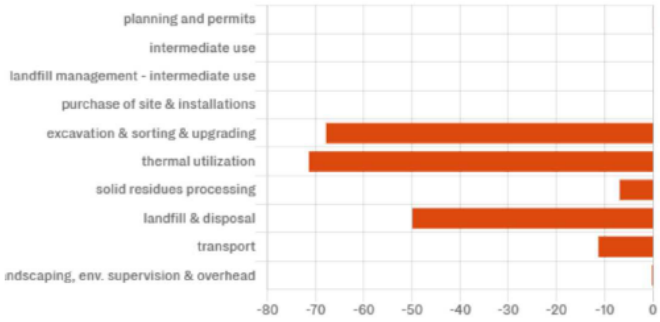


9 houshold

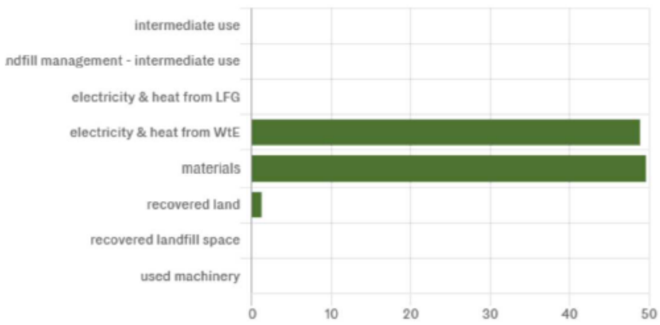
Final results

Description	Value	Unit
Net present value of costs	-206.0	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	-67.8	Mio Euro
thermal utilization	-71.4	Mio Euro
solid residues processing	-6.86	Mio Euro
landfill & disposal	-49.9	Mio Euro
transport	-11.3	Mio Euro
landscaping, env. supervision & overhead	-0.213	Mio Euro
Net present value of avoided revenues	0.0	Mio Euro
Net present value of revenues	99.7	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	48.9	Mio Euro
materials	49.7	Mio Euro
recovered land	1.18	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)	-106.0	Mio Euro
Specific net present value (SNPV)	-59.9	Euro/Mg

Net present value of costs [Mio Euro]



Net present value of revenues [Mio Euro]



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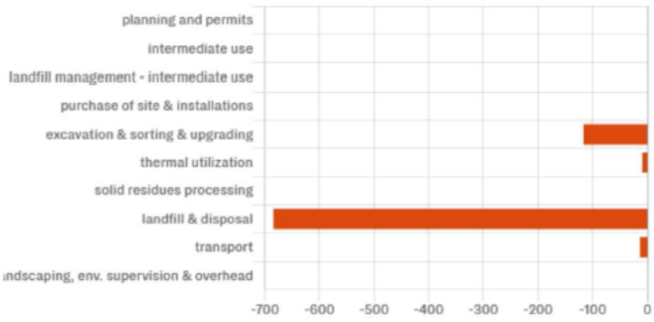
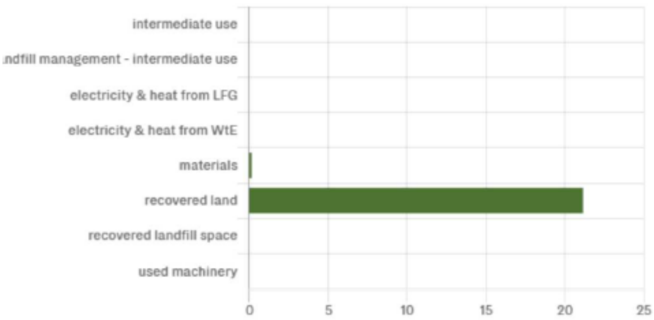
Final results

Description	Value	Unit
Net present value of costs	-823.0	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	-117.0	Mio Euro
thermal utilization	-9.09	Mio Euro
solid residues processing	0.0	Mio Euro
landfill & disposal	-684.0	Mio Euro
transport	-12.8	Mio Euro
landscaping, env. supervision & overhead	-0.0746	Mio Euro
Net present value of avoided revenues	0.0	Mio Euro
Net present value of revenues	21.3	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	0.129	Mio Euro
recovered land	21.2	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)	-802.0	Mio Euro
Specific net present value (SNPV)	-229.0	Euro/Mg

Net present value of costs [Mio Euro]



Net present value of revenues [Mio Euro]



Contact

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