FRAMEWORK FOR THE EVALUATION OF ANTHROPOGENIC RESOURCES:

Economic analysis of recovering recyclable materials from old landfills

Concept

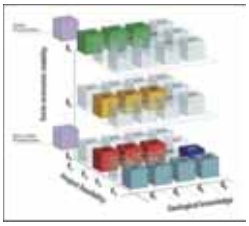

Figure 1: United Nations Framework Classification for Fossil Energy and Mineral Reserves and Resources 2009 (UNFC-2009).

The goal of this study is to apply the primary resource classification framework UNFC-2009 to a landfill-mining project, to identify it as a **'reserve'** (current economic extraction by a defined project and sale confirmed) or a **'resource'** (reasonable prospects for economic extraction by a defined project and sale in the foreseeable future) or none of both, and to reveal critical factors for the classification of the project. Three crucial points need to be considered (cf. Figure 1):

1) Knowledge on composition, size and quality of the extractable resource stock (G-axis)

2) Project and technical feasibility: Under what technical conditions can materials be extracted and valorized? (F-axis)

3) Socioeconomic viability (E-axis)

Materials & Methods

Evaluation steps	Goal	Localization in UNFC-2009	Methods for decision foundation	Preliminary classification indicators
Prospection	First estimates on resource potential: Selection of a project	-	Macro scale MFA: Analysis & evaluation of landfill statistics & literature data on waste composition	General characteristics of site & landfill, e.g. type of landfill
Exploration	Gain knowledge on composition of the deposit & share of extractable & potentially usable materials	G-Axis	Detailed investigation of the landfill: - Data from waste disposal log book & waste sampling & analysis - Micro scale MFA with specific recovery efficiencies	Certainty of knowledge on the landfill´s extractable material content
	Identify different options for technologies & project set-ups	F-Axis	Technology assessment, policy framework analysis, stakeholder analysis	Maturity of technology, institutional structures & permissions
Evaluation	Socioeconomic viability of extraction: Direct financial effects & non-monetary modifying factors	E-Axis	DCF analysis & cut-off values for key parameters	Net Present Values (NPV) a) NPV > 0: Reserve b) NPV < 0: Resource or not?
Classification	Combination of all criteria & classification under UNFC-2009			

Table 1: Operative procedure for evaluating a landfill-mining project under UNFC-2009 based on Winterstetter et al. 2015. MFA = Material Flow Analysis, DCF = Discounted Cash Flow Analysis.

- **Exploration:**
  - Relevant material and energy flows quantified in a Material Flow Analysis to identify the extractable and potentially usable share of materials.
  - 4 scenarios: 2 alternatives for the combustible waste fraction's thermal treatment & 2 stakeholder perspectives: **On-site vs. Off-site incineration** & **Public (Macro) vs. Private (Micro) perspective**
- **Evaluation:**
  - Discounted Cash Flow analysis including Monte Carlo simulations.
  - Macro scenarios: Potential greenhouse gas emission savings monetized via a hypothetical CO_2 tax as example of including non-monetary environmental externalities, longer avoided aftercare costs and lower discount rate.
- **Classification**:
  - If Net Present Value (NPV) > 0: 'Reserve'
  - If NPV < 0: 'Resource' or not? => Only if reasonable prospects to become economically viable within the next 20 years

Evaluation based on data from the **Enhanced Landfill Mining (ELFM) project** in Belgium

- 16 mio t of waste landfilled on 1.3 km²
- 50 % municipal solid waste, 50 % industrial waste
- Landfill's active operation period: 1970s - 2003
- Mining activities to start in 2017 for 20 years
- Initiated by former landfill operator in cooperation with external partners
- Full valorization of waste streams as material or energy planned

Results

	Low estimate	Medium estimate	High estimate
Regained salable land (m²/a)	490,000	520,000	550,000
On-Site incineration: Electricity (MWh/a)	190,000	230,000	280,000
Off-Site incineration: RDF sold to external incinerator (t/a)	130,000	170,000	210,000
Stones / minerals (t/a)	50,000	85,000	120,000
Nonferrous metals (t/a)	1,200	2,400	3,600
Fine metals (t/a)	6,800	9,200	11,700
Metals from RDF preparation (t/a)	2,200	4,600	7,000
Ferrous metals (t/a)	7,000	14,000	22,000
Amount of materials to be re-landfilled (fines, sorting residues, incineration ash t/a)	560,000	480,000	400,000

Table 2: Potentially recoverable & salable quantities (Total amount of annually excavated waste: 807 000 t wet matter)

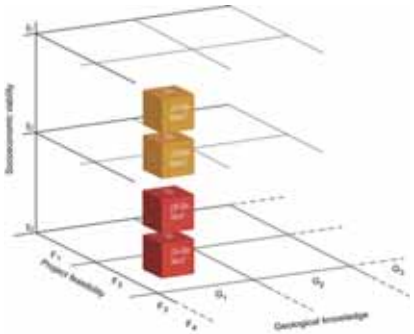

Figure 2: The applicability of UNFC-2009 illustrated by classifying the 4 scenarios of the original landfill-mining project

The NPVs for the 4 landfill-mining scenarios, calculated based on a range of estimates regarding potentially recoverable and salable quantities (Table 2), turned out to be negative, ranging between -197 million € in the best and -284 million € in the worst case. This implies that none of the project's variations is currently economically viable, and thus the landfill cannot be classified as 'reserve'.

Optimistic forecasts assume metal prices to double by 2035 and operating cost of sorting plants to decrease by 20 % due to the use of more energy efficient technologies (Table 3). In addition, operators of incinerators will pay, due to overcapacities, at least 10 € per ton RDF made from the landfill's combustible materials.

In that case the off-site scenarios of the landfill mining project would yield NPVs of in average -1.3 million € for the scenario "Off-site Micro" and 40 million € for the scenario "Off-Site Macro".

For the on-site incineration scenarios, with 20 % lower sorting costs, doubling metal prices and feed-in tariffs for electricity assumingly to double by 2035, the scenario "On-Site Micro" would yield a negative NPV of -54 million € and the scenario "On-Site Macro" would result in a positive NPV of 88 million €.

Therefore the macro-perspective scenarios are classified as potentially economic (E2), while the micro-perspective scenarios are considered as not even remotely economic (E3).

All scenarios are classified as potentially feasible (F2).

In terms of "knowledge on the landfill´s extractable material content", all scenarios are graded with „G1", as the quantities contained in the landfill depending on applied technologies can be estimated with a high level of confidence.

Scenarios in: / Assumed future parallel changes	Secondary metal prices (Current: Non-ferrous: 1220 €/t, Ferrous: 190 €/t*)	Feed-in tariffs electricity (Current: 45 €/MWh*)	Gate fees incineration (Current: Pay 65 €/t RDF*)	Sorting costs (Current: in average 22 €/t)	Expected NPV (mio €)
On-Site Macro	x 2	x 2	-	- 20 %	88
Off-Site Macro	x 2	-	Receive 10 € /t	- 20 %	40
Off-Site Micro	x 2	-	Receive 10 € /t	- 20 %	-1.3
On-Site Micro	x 2	x 2	-	- 20 %	-54

Table 3: Several assumed future changes in parameters related to metal sales, sorting costs and thermal treatment and the expected NPVs. *Average price for the period 2010 – 2014 in Belgium.

Combining those three criteria, the macro-perspective scenarios are categorized as E2F2G1 ('resources') and the micro-perspective scenarios are evaluated as E3F2G1 ('non- resources') (Figure 2).

Outlook

Although the applicability of UNFC-2009 to landfill mining has been proven successfully, further research is needed to define specific, quantifiable criteria for categorizing various kinds of anthropogenic resources under UNFC-2009. This will improve the estimates of global total resource inventories and their extractable fractions by considering various boundary conditions, allowing for fair comparisons between naturally occurring and anthropogenic resource deposits.

[1]Reproduced courtesy of the United Nations Economic Commission for Europe.

Winterstetter, A., Laner, D., Rechberger, H., & Fellner, J. (2015). Framework for the evaluation of anthropogenic resources: A landfill mining case study–Resource or reserve?. *Resources, Conservation and Recycling*, *96*, 19-30.

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