Enhanced Landfill Mining in the EU-28: rationale, opportunities and challenges

Peter Tom Jones (General Co-ordinator EURELCO)
The landfill situation in EU-28
Enhanced Landfill Mining (ELFM): rationale and definition
The rise of the ELFM concept
Why EURELCO?
Conclusions

SNEAK PREVIEW: EURELCO Animation Film with Ray Cokes
The Landfill Situation in EU-28 – Problems and Opportunities
How many landfills in the EU-28?

- Sufalnet4EU: > 150,000 landfills
- Hogland et al, *Proc. ELFM I*, 2010: 350,000 – 500,000 landfills and dumps
- Bottom-up questionnaire EURELCO: 500,000 figure is most probably an underestimate (see infra)

Europe’s landfills vary in size, depth, type

- Single Use USW Landfills, Mixed USW/IW Landfills, monolandfills containing one particular Industrial Waste residue
- Sanitary (managed) landfills (cf. Landfill Directive) versus unmanaged “non-sanitary” landfills and even waste dumps
- Publicly owned versus privately owned
**Objective Landfill Directive:**

To prevent or reduce as far as possible negative effects on the environment, in particular on surface water, groundwater, soil, air, and on human health from the landfilling of waste by introducing stringent technical requirements for waste and landfills.

**Landfill Directive defines different categories of waste and applies to all landfills, defined as waste disposal sites for the deposit of waste onto or into land.**

**Landfills are divided into three classes:**

- Landfills for hazardous waste;
- Landfills for non-hazardous waste;
- Landfills for inert waste.
EU Waste Management is governed by the EU Waste Hierarchy (Ladder of Lansink)

Key attention for climbing the ladder for freshly created Urban Solid Waste and Industrial Waste FLOWS, leading to:

- Improved recycling technologies
- Incineration RUSW with energy recovery
- Phasing out landfilling
- Making sure that remaining landfilling is safe!
EU Waste Management – A global perspective: EU does well!
Nevertheless... Landfilling & incineration in the EU-28 remain high
Landfill Directive has been instrumental in improving safety of landfilling for FRESHLY produced waste in many EU Member States

However, many questions remain:

• What about the historic legacy of landfills that were created prior to the Landfill Directive (1999)?
• Are these landfills safe?
• Is remediation required?
• What is the cost of remediation?
• Do they offer resource recovery opportunities?
Landfills in EU-28 - Parliamentary Question on Landfills in EU (18-5-2015)

Form for tabling a question for written answer (Rule 130)

Select only one addressee:

- President of the European Council
- Council

- Vice-President / High Representative
- Commission

Priority question

Author(s): Hilde VAUTMANS

Subject: Stimulating Enhanced Landfill Mining as part of the transition to a circular economy
• Many landfills pose major environmental and human health risks if left unaddressed. Member States will have to use taxpayers' money to remediate the most problematic sites. Has the Commission performed any calculations on the future remediation costs for the EU-28?

• Contrastingly, the EU's landfills contain significant amounts of base and critical metals, minerals, energy carriers etc. which can be recovered. Has the Commission performed a mapping of the resource potential of its 150,000 to 500,000 landfills?

• To be cost-effective for private companies, Enhanced Landfill Mining requires cutting-edge separation, transformation and upcycling technologies to deliver metals, materials, energy carriers and land. Does the Commission plan to support R&D and/or pilot activities, as well as demonstration projects, which explicitly address Enhanced Landfill Mining?
• Has the Commission performed any calculations on the future remediation costs for the EU-28? NOT YET [EC is confident that Landfill Directive avoids health and environment risks]

• Has the Commission performed a mapping of the resource potential of its 150,000 to 500,000 landfills? NOT YET [EC would like to receive these data but hasn’t received them yet]

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EURELCO Member States were contacted to provide data:

- Amount of presently still operational landfills
- Estimated total amount of landfills
- Distribution sanitary landfills (preceding and/or in compliance with EU Landfill Directive/ non-sanitary landfills (in % of landfills)
- Distribution USW/industrial landfills (in % of landfills, in amounts not weights)

Responses received from 13 EU Member States, combined with:

- Current landfill rate (%) taken from EUROSTAT 2012 data
- Definition: share of landfilled waste versus total waste generated, excluding major mineral waste,
EURELCO – Some Regions/Member States have accurate data, others don’t

E.g. Landfill map for Region of Flanders: total number of inventorised landfills: 2,061 (87 km²); only 28 operational landfills in 2015.
EURELCO – Bottom-up gathering of data (May-October 2015)

Legend

Amount of presently still operational landfills

Distribution sanitary landfills (preceding and/or in compliance with EU landfill directive / non sanitary landfills (in % of landfills)

Distribution USW/industrial landfills (in % of landfills, in amounts not weights

Estimated total amount of landfills (when data are indicated between brackets) this implies it is an estimate based on the amount of municipalities multiplied by an average amount of 5 landfills per municipality

0% - 20%  20% - 40%  40% - 60%  60% - 80%  80% - 100%

Current landfill rate(% i.e. share of landfilled waste versus total waste generated, excluding major mineral waste (EUROSTAT 2012 data)
EURELCO – Infographic

Landfills in Europe

Timeline of waste-related directives in Europe

Legend

- Amount of presently still operational landfills
- Distribution sanitary landfills (preceding and/or in compliance with EU landfills directive) vs non-sanitary landfills (% of landfills)
- Distribution USW/industrial landfills (% of landfills, in amounts not weights)

Estimated total amount of landfills (when data are indicated between brackets, this implies it is an estimate based on the amount of municipalities multiplied by an average amount of 5 landfills per municipality)

Current landfill rate%: N.A. share of landfilled waste versus total waste generated, excluding major mineral waste (EUROSTAT 2012 data)

EU(28): 500,000 landfills

Non sanitary landfills
Sanitary landfills
Key messages:

- 90% of EU’s landfills are essentially “non-sanitary landfills”, preceding the Landfill Directive
- They will need remediation – estimated “classic remediation” cost for EU-28 is between 0.1 and 1 trillion euro (see infra)

BUT...

- These landfills constitute enormous resource stocks
- ELFM, combined with remediation, can deliver materials, energy and land, while drastically reducing remediation costs
What is Enhanced Landfill Mining – Rationale and Definition
Enhanced Landfill Mining =
“the integrated valorisation of landfilled waste streams as both materials (Waste-to-Material) and energy (Waste-to-Energy), using innovative transformation technologies and respecting the most stringent social and ecological criteria.”

Enhanced Landfill Mining in view of multiple resource recovery: a critical review (Jones et al., JCLEPRO, 2013)
ELFM Definition relevant for MSW landfills and industrial residue landfills containing critical metals

Source: Binnemans, Jones et al., JCLEPRO, 2014

Keynote Prof. Friedrich today
Keynote Yves Tielemans today
ELFM – Complementary to recycling

1. Recycling
2. Substitution
3. Primary mining

Raw materials production

End-of-Life

New scrap

Metals, alloys and compounds

Product manufacture

Use

Natural resources

Primary mining

1. Recycling/Urban Mining

2. Substitution
ELFM – Complementary to recycling

Enhanced landfill mining

- 150,000-500,000 Landfills in EU-28
- Single-use USW
- Mixed USW/IW
- Monolandfills containing industrial residues

ELFM resources

Natural resources

Raw materials production

Product manufacture

Metals, alloys and compounds

End-of-Life

New scrap

Use

1. Recycling/Urban Mining

2. Substitution

3. Primary mining
ELFM – With respect to other scenarios
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ELFM – A flow sheet for USW/MSW landfills

(cf. Keynote Yves Tielemans, with focus on plasma gasification)
ELFM and advanced Thermochemical conversion – beyond incineration: from downcycling to upcycling

Improving the intrinsic business case of ELFM projects
**ELFM** Industrial residue landfills (mostly privately owned)

MaRes

(EIP) METGROW+

(cf. Keynote Prof. Friedrich)
ELFM Industrial residue landfills

E.g. EU H2020 METGROW+ project coordinated by VTT, Finland

Relevance: bauxite residue, goethite sludge, non-ferrous fayalite slags, tailings from Cu industry, incineration ashes etc.

(cf. Keynote Prof. Friedrich)
The rise of the ELFM concept — Achievements
Enhanced Landfill Mining (ELFM) has gradually obtained more coverage and credibility in the EU:

- Flanders: Multi-actor research consortium since 2008
  www.elfm.eu
ELFM Consortium Governance model
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- Several national research projects are running
### Nationally funded R&D projects

<table>
<thead>
<tr>
<th>Name_project</th>
<th>Funding_Agency (Budget)</th>
<th>Partners</th>
<th>Which_landfill? (location) - owner, size, type</th>
<th>Timing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Closing the Circle</td>
<td>Flemish Government + Private Funding (JMR) (6 M€ for IWT O&amp;O ELF + 1 M€ for MIP ICON PLASMAT)</td>
<td>NEW-MINE: KU Leuven, JMR, UA Others: VITO, Uhasselt</td>
<td>Remo landfill (Houthalen-Helchteren, Flanders/Belgium) - JMR, 16,5 Mtonne, mainly MSW)</td>
<td>2011-2016</td>
</tr>
<tr>
<td>LAMIS</td>
<td>Austrian Research Promotion Agency (FFG) (Budget: 0,57 M€)</td>
<td>NEW-MINE: MUL Others: More than 20 partners</td>
<td>Halbenrain Landfill (Styria, Austria) - AVW Mürzverband, 10 ha, MBT-treated MSW</td>
<td>2013-2016</td>
</tr>
<tr>
<td>Landfill Mining 2.0</td>
<td>Funder: Swedish Innovation Agency (VINNOVA) (0,23 M€ subsidy)</td>
<td>NEW-MINE: LIU, Stena Others: Nordvästra Skånes Renhållnings, Tekniska Verken</td>
<td>Gärstad landfill (Linköping, Sweden) – Tekniska Verken, 4 Mtonne MSW and other [2 other landfills are in this project as well]</td>
<td>2015-2017</td>
</tr>
</tbody>
</table>
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- Several national research projects are running
- Erection EUROPEAN ENHANCED LANDFILL MINING Consortium in March 2014
  - [www.eurelco.org](http://www.eurelco.org)
- EURELCO received EIP RMC Status
Mission. To be a an open, quadruple helix network that supports the required technological, legal, social, economic, environmental and organisational innovation with respect to Enhanced Landfill Mining within the context of a transition to a circular, low carbon economy.
EIP RMC status EURELCO

- An RMC is a joint undertaking by several partners, who commit to activities aimed at achieving the EIP's objectives between 2014 and 2020.

- Early 2014 the High Level Steering Group of the EIP confirmed that 80 commitments fulfilled the required criteria.

- EURELCO was one of the 80 commitments that were given the official status of “EIP RMC, thereby corroborating the EU-wide relevance of the vision and mission of EURELCO.

- The EURELCO RMC was initially signed by KU Leuven, VITO, Group Machiels (Belgium), Stena Metall & Linköping University (Sweden) and VTT (Finland).
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- ELFM is key part of new EIT KIC Raw Materials
Western co-location centre, hosted at KU Leuven, unites industrial and research core partners from Belgium, Germany and the Netherlands.

Main areas of innovation will be:

- Recycling of complex End-of-Life products and urban mining;
- Recovery of valuable RM from industrial residues and landfill mining;
- Circular economy;

Also “Eastern” CLC with MUL works on this item of ELFM
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- EURELCO developed Interreg Europe COCOON network
Rationale

- Objective: “to develop, integrate and improve relevant ELFM² policy instruments, while increasing subsidies through operational programmes (OPs) for these resource efficiency projects.”
- 8 targeted policy instruments include (a) ELFM² policy in Flanders (BE), Styria (AT), the Netherlands and Veneto region (IT) and (b) funding of ELFM² projects through the OPs in Cyprus, Eastern Macedonia and Thrace (GR)), Hungary and Malta.

Participation of relevant Public Bodies from 9 EU Regions corroborates growing interest for ELFM amongst governmental actors
Why EURELCO?
Non-technical barriers are manifest:

- Social acceptance (NIMBYISM)
- Legal (e.g. Landfill Directive & Waste Framework Directive)
- Economics (public versus private benefits)

Nevertheless, acceptance of the concept and commercial breakthrough of ELFM less straightforward than for urban mining of critical metals.
**Quadruple Helix Innovation**

- Government, Academia, Industry and Citizens collaborating together to drive structural changes far beyond the scope of any one organisation could achieve on its own.
- Involve all stakeholders in quadruple helix to innovate and experiment in real world settings, in creating frictionless ecosystems.
The landfill is stuck in a dump regime

• EU Landfill Directive strongly advocates isolation, control, final closure and post-monitoring
• This perception of landfills as hazardous, end stations for obsolete materials displays clear signs of path-dependency and lock-in
• The fact that ELFM is not part of EU policy and regulatory frameworks causes multiple challenges and uncertainties
• Such uncertainties regarding the market rules (e.g. landfill tax for fractions that need to be rehandled) make it difficult for actors to foresee the outcome of their investments
• Most of the benefits of landfill mining only occur on the societal level = key policy challenge → coupling ELFM with remediation needs can offer a way forward!
Examples of policy and regulatory implications

• Landfill prohibitions and taxes impose potential waste disposal problems and high additional costs for landfill mining projects

• A resource-effective and cyclical use of the extracted materials could also be prevented by strict guiding values on heavy metals

• Current landfill and waste regulations have contributed to unfavourable markets for energy carriers recovered from landfills (i.e. gate fees)
Focus on ELFM in broader context of circular economy. Landfill = dynamic stock of resources versus static, eternal disposal

The challenge is to combine the top-down public perspective with a bottom-up private perspective (companies willing to perform ELFM projects)

Coupling ELFM + remediation is the way forward
Conclusions
Conclusions – Let’s turn the landfill problem into an opportunity

90% of Europe’s 500,000 + landfills are non-sanitary landfills for which the Landfill Directive does not offer a solution

Dedicated inventory exercises based on log books, geophysical studies, drillings and economic assessments are required in order to obtain better data for EU-28
Conclusions – Let’s turn the landfill problem into an opportunity

90% of Europe’s 500,000 + landfills are non-sanitary landfills for which the Landfill Directive does not offer a solution

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ELFM requires a paradigm shift: landfills need to be taken out of the dump regime → to be reconsidered as “resource reservoirs awaiting valorisation”

ELFM can be combined with remediation, drastically lowering overall costs

ELFM triggers technological innovation (circular economy framework) and leads to local job creation

Private businesses are ready but need stable frameworks
Thank you for your attention – Enjoy “The benefits of landfill mining”
ELFM potential - Appendix
**Economic benefits**

- **Avoidance of landfill remediation costs:**
  - 0.1-1 trillion € (if ELFM concept is used for all EU-landfills)
  - A new resource recovery economy, with significant short, medium and long term potential for EU SMEs in EU-27 and in the rest of the world: CH₄ extraction (*in situ*); Organic based materials (WtM or WtE) (*ex situ*); Metals (*ex situ* and/or *in situ*); Materials for building and construction (*ex situ*)

- **Recovery of valuable land (*in situ* or *ex situ*)**
Impact of ELFM on a EU-scale (see Jones et al., 2013)

Strategic benefits through resource recovery

• Improve EU’s *materials autonomy* :
  • Reducing pressure on primary raw materials (fossil fuels and non-energy raw materials)
  • Fostering the use of secondary raw materials:
    • Aggregate figure: ~5% of the current DMC/year for EU-27, for 25 years
    • Plasmarok slag (a.o. replacement for cement clinker): 250–840 Mtonne for 25 years
  • (Critical) Metal recovery from, especially, industrial process residue landfills; tailings, sludges, slags and ashes (see review Binnemans et al., 2015): metal recovery potential substantial (detailed mapping of potential on-going in WG1 EURELCO)

• Improve EU’s *energy autonomy* :
  • Contributing to EU’s renewable energy target through accelerated CH₄ uptake through *in situ* LFM: 7 million TOE ~3% of the EU-27 renewable energy target for 2020
  • Contributing to EU’s renewable energy target (WtE from SRF (mixed organic) from *ex situ* LFM: an additional 0,4-1,1 million TOE )
Impact of ELFM on a EU-scale (see Jones et al., 2013)

Health and environment

- Lower the EU’s carbon footprint (benchmark with direct EU $\text{CO}_2(\text{eq})$ emissions: 4600 Mtonne $\text{CO}_2(\text{eq})$/year):
  - Avoided $\text{CO}_2(\text{eq})$ emissions due to $\text{in situ}$ CH$_4$ mining of 112 – 139 Mtonne/year;
  - Avoided $\text{CO}_2(\text{eq})$ emissions due to net carbon balance, from a full EU-27 ex situ LFM approach (versus in $\text{situ}$ only approach, for 150.000-500.000 landfills): extra 15 - 75 Mtonne $\text{CO}_2(\text{eq})$/year
  - Plasmarok slag replacing cement clinker: 3-11 Mtonne $\text{CO}_2(\text{eq})$/year
  - Use of $\text{CO}_2$ in horticulture

- Land reclamation ( >2800 - 6000 km$^2$, nature-urban-industrial purposes)
- Avoiding future human health and environmental issues due to landfill pollution problems
- Reducing environmental & health impact associated with primary mining of energy and non-energy materials
Impact of ELFM on a EU-scale (see Jones et al., 2013)

Social benefits

• Creation of new jobs associated with the start-up of new, SME-driven markets:
  • Up to 300 FTE new jobs for the Remo landfill site (ex situ mining)
  • Up to 240,000-800,000 new jobs in EU-27 (for full implementation of ELFM framework)