Integrating Anthropogenic Resources into UNFC-2009: Update on Case Studies

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1. The Bigger Picture
2. Goal & Motivation
3. Application of Primary Resources Concepts to Anthropogenic Resources
4. The Case of Old Landfills, Obsolete PCs and In-Use Wind Turbines
5. Conclusion & Outlook
1. The Bigger Picture

Need for final sinks **GROWING!!**

- In-use stocks
- Waste flows
- Obsolete Stocks **GROWING!!**

Use & disposal of materials & goods **GROWING!!**

- Energy input
- Emissions
- Local environmental pollution
  - … **GROWING!!**

Raw materials extracted **GROWING!!**

Low grade ores
The Bigger Picture 2

- Raw materials extracted
- Waste reduced
- Emissions saved
- Supply security
- ... GROWING!!

Need for final sinks

UBERN MINING & RECYCLING

GROWING!!

Use & disposal of materials & goods
GROWING!!

• Energy input
• Emissions
• Local environmental pollution
• ...

Raw materials extracted

Low grade ores
2. Goal & Motivation

Goal: Fit anthropogenic resources into UNFC-2009

Why?

- **Holistic view** of resource availability
- Information for decisions makers in **waste management**
- Feedback for **design for recycling**

→ **Systematic & transparent** method necessary
3. Application of a Primary Resource Classification Framework to Anthropogenic Resources
Human Activity

(1) Human influence
(2) Diverse & scattered sources
(3) Many diverse recoverable fractions
(4) Time of genesis shorter
(5) High uncertainties
(6) Anticipating future obsolete stocks & waste flows by investigating in-use stocks
(7) Often positive externalities

Winterstetter et al. Submitted a.
Availability

- "Push" vs. "Pull" situation:
  - "Pull": Landfill can be mined for resource recovery
  - "Push": Due to imminent pollution threat some landfills must be mined, e-waste flows must be treated in any case (EU law)
4. Three show cases

In-Use Stock: NdFeB magnets in wind turbines

Waste Flow: Obsolete PCs

Obsolete Stock: Old landfill
## Case Studies: Results

<table>
<thead>
<tr>
<th></th>
<th>Old landfill</th>
<th>Obsolete PCs (EU)</th>
<th>Permanent magnets in wind turbines</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Present</td>
<td>Potential future</td>
<td>Scenario 1 (High income &amp; collection rate)</td>
</tr>
<tr>
<td>NPV total</td>
<td>-277 Mio.</td>
<td>46 Mio.</td>
<td>96,000</td>
</tr>
<tr>
<td>NPV in € / t</td>
<td>-17</td>
<td>2.9</td>
<td>120</td>
</tr>
<tr>
<td>excavated waste materials / t collected PCs / t magnetic scrap</td>
<td>98</td>
<td>120</td>
<td>340</td>
</tr>
</tbody>
</table>
Classification under UNFC-2009
5. Conclusion & Outlook

- Classification of different types of anthropogenic resources under UNFC-2009 possible
- Operative evaluation procedure & guidelines developed
- Criteria in line with the classes of UNFC-2009 defined, e.g. in-use stock = F4

Challenges:
- How to deal with the inclusion (monetization) of non-monetary effects: E-axis?
- System boundaries of “project” for dynamic waste flows?

Common platform for evaluating
a) Different types of anthropogenic resources
b) Geogenic & anthropogenic resources
Thank you for your attention! 😊

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Many thanks to the contributors:

David Laner
Johann Fellner
Literature


<table>
<thead>
<tr>
<th></th>
<th>Obsolete Stocks</th>
<th>Waste Flows</th>
<th>In-Use Stock</th>
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<tbody>
<tr>
<td></td>
<td>(Old Landfill)</td>
<td>(Obsolete PCs)</td>
<td>(NdFeB Magnets)</td>
</tr>
<tr>
<td><strong>E1</strong></td>
<td>Project yields positive NPV</td>
<td>KMF: Labor costs, avoided disposal costs, secondary raw material prices</td>
<td>KMF: Secondary raw material prices, REE separation costs in hydrometallurgical scenario</td>
</tr>
<tr>
<td><strong>E2</strong></td>
<td>Project yields negative NPV, but due to future expected changes in key modifying factors (KMF), cut-off values might be reached</td>
<td>KMF: Treatment costs, secondary raw material prices, gate fees for energy recovery</td>
<td></td>
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<tr>
<td><strong>E3</strong></td>
<td>Project yields negative NPV</td>
<td></td>
<td>or evaluation is at too early stage to determine economic viability</td>
</tr>
<tr>
<td><strong>F1</strong></td>
<td>Feasibility of extraction by a defined development project or mining operation has been confirmed</td>
<td></td>
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<tr>
<td></td>
<td>▪ Existing legal framework</td>
<td></td>
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<td></td>
<td>▪ Existing societal, institutional &amp; organizational structure</td>
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<tr>
<td></td>
<td>▪ Mature technologies applied</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>▪ Project status: Ongoing activities</td>
<td></td>
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<tr>
<td></td>
<td>Scenario 1</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Existing infrastructure &amp; public awareness for PC collection via EPR (in line with WEEE directive).</td>
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<tr>
<td><strong>F2</strong></td>
<td>Feasibility of extraction by a defined development project or mining operation is subject to further evaluation, at least one of the F1 criteria is not fulfilled</td>
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<tr>
<td></td>
<td>▪ No legal framework for landfill mining</td>
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<td></td>
<td>▪ Positive public perception</td>
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<td></td>
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<tr>
<td></td>
<td>▪ Mainly design &amp; planning activities ongoing</td>
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<td></td>
<td>▪ Operations only on a pilot scale.</td>
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<td></td>
<td>Scenario 2</td>
<td></td>
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<tr>
<td></td>
<td>Weakly enforced laws</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Poor collection infrastructure</td>
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<tr>
<td></td>
<td>Low awareness about source separation</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Application of established recycling methods</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Interference with informal recycling sector (high uncertainties about collection rates).</td>
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<tr>
<td><strong>F3</strong></td>
<td>Feasibility of extraction by a defined development project or mining operation cannot be evaluated due to limited technical data.</td>
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<tr>
<td></td>
<td>Extraction, processing &amp; valorization technologies exist and are planned to be applied, but the project is not sufficiently advanced to determine the quantity &amp; quality of potentially recoverable material, F1 criteria are widely not fulfilled</td>
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</tbody>
</table>

Winterstetter et al. Submitted a
| F4 | In situ (in-place) quantities that will not be extracted by any currently defined development project or mining operation.  
• F1 criteria are not fulfilled, also not (yet) existing technologies  
• F4.1 – F4.3 describe the current state of technological development:  
  o F4.1: Technology under development, but no type-specific applications (yet)  
  o F4.2: Technology is researched, but pilot studies are not yet available  
  o F4.3: Technology for recovery is not currently under research or development  
|   | In-use stocks are classified as F4 as they are currently not available for mining.  
|   | No legal framework for treating obsolete wind turbines  
| Scenario 1 (re-use) |  
| F4.1: Existing research project on the re-use of NdFeB-magnets from hybrid cars & e-vehicles  
| Scenario 2 (hydrometallurgy) |  
| F 4.2: Technology currently being researched \(\text{e.g. } Ellis \text{ et al., 1994; Itakura et al., 2006; Itoh et al., 2009}\), but no successful pilot studies have yet been completed / no published data |
| G1 | The stock’s / flow’s volume, composition & the applied technologies’ recovery efficiencies can be estimated with a high level of confidence to assess the share of potentially extractable & usable materials*  
Alternative: P90 => Low estimate** |
<table>
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</thead>
<tbody>
<tr>
<td><strong>Scenario 1</strong></td>
<td><strong>Scenario 2</strong></td>
</tr>
</tbody>
</table>
| • Volume & composition of PC waste flow is well known  
• Recovery efficiencies are well known | • Volume & composition of waste flow is well known, however significant uncertainties about collection rate due to informal sector  
• Recovery efficiencies can be estimated with sufficient detail |
| G2 | The stock’s / flow’s volume, composition & the applied technologies’ recovery efficiencies can be estimated with a medium level of confidence to assess the share of potentially extractable & usable materials*  
Alternative: P50 => G1+G2 = Best estimate** |
| **Scenario 2** |
| • Medium level of confidence about quantity & composition of landfilled material (based on sample excavations & the landfill’s logbook data).  
• Recovery efficiencies sufficiently known |
| G3 | The stock’s / flow’s volume, composition & the applied technologies’ recovery efficiencies can be estimated with a low level of confidence to assess the share of potentially extractable & usable materials*  
Alternative: P10 => G1+G2+G3 = High estimate** |
<p>| G4 | Quantities estimated during the exploration phase, subject to a substantial range of uncertainty &amp; major risk that no mining operation will be implemented to extract these quantities |</p>
<table>
<thead>
<tr>
<th>Phases &amp; UNFC axes</th>
<th>Goal</th>
<th>Influencing factors</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Prospection</td>
<td>Selection of a deposit to be mined (preconditions)</td>
<td>Availability: In-use stock, Obsolete stock, Waste flows&lt;br&gt; Mining / handling condition: Push, Pull&lt;br&gt; System Variables: Type, Location, Volume, Composition</td>
</tr>
<tr>
<td>G Axis</td>
<td>First estimates on resource potential</td>
<td></td>
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<tr>
<td>2. Exploration</td>
<td>Knowledge on the deposit’s share of extractable &amp; potentially usable materials</td>
<td>Technical feasibility &amp; Project status: Legal, institutional, organizational &amp; societal structures, Different options for technologies &amp; project set-ups for extraction &amp; processing with specific efficiencies &amp; maturity, Project status</td>
</tr>
<tr>
<td>G Axis, F-Axis</td>
<td></td>
<td></td>
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<tr>
<td>3. Evaluation</td>
<td>Socioeconomic viability of extraction &amp; utilization</td>
<td>Modifying factors: Prices for secondary products, Costs, Avoided costs, Indirect financial effects &amp; monetized external effects</td>
</tr>
<tr>
<td>E-Axis</td>
<td></td>
<td></td>
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<tr>
<td>4. Classification</td>
<td>Combination of all criteria &amp; classification under UNFC-2009</td>
<td></td>
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</tbody>
</table>
Investigated Scenarios

Old landfill Belgium

Obsolete PCs (EU)

Permanent magnets in wind turbines in Austria

Resource potential: Extractable & potentially usable materials

Legal, institutional, organizational & societal structures

Different technological options

Modifying Factors: Prices & (Avoided) Costs

Landfill Mining (LFM) present

LFM Future: Metal prices x2, Sorting Cost –20%, Incineration RDF: Revenues instead of costs

PCS1: City 1: High income & collection rate, Mech.-manual dismantling

PC S2: City 2: Low income & collection rate, manual dismantling

WT S1: Re-use of magnets

WT S2: Hydrometallurg. Extraction of Nd, Dy, Pr, Fe, B

Evaluation

Prospection & Exploration