# Life Cycle Assessment of Mining an Old Danish Landfill

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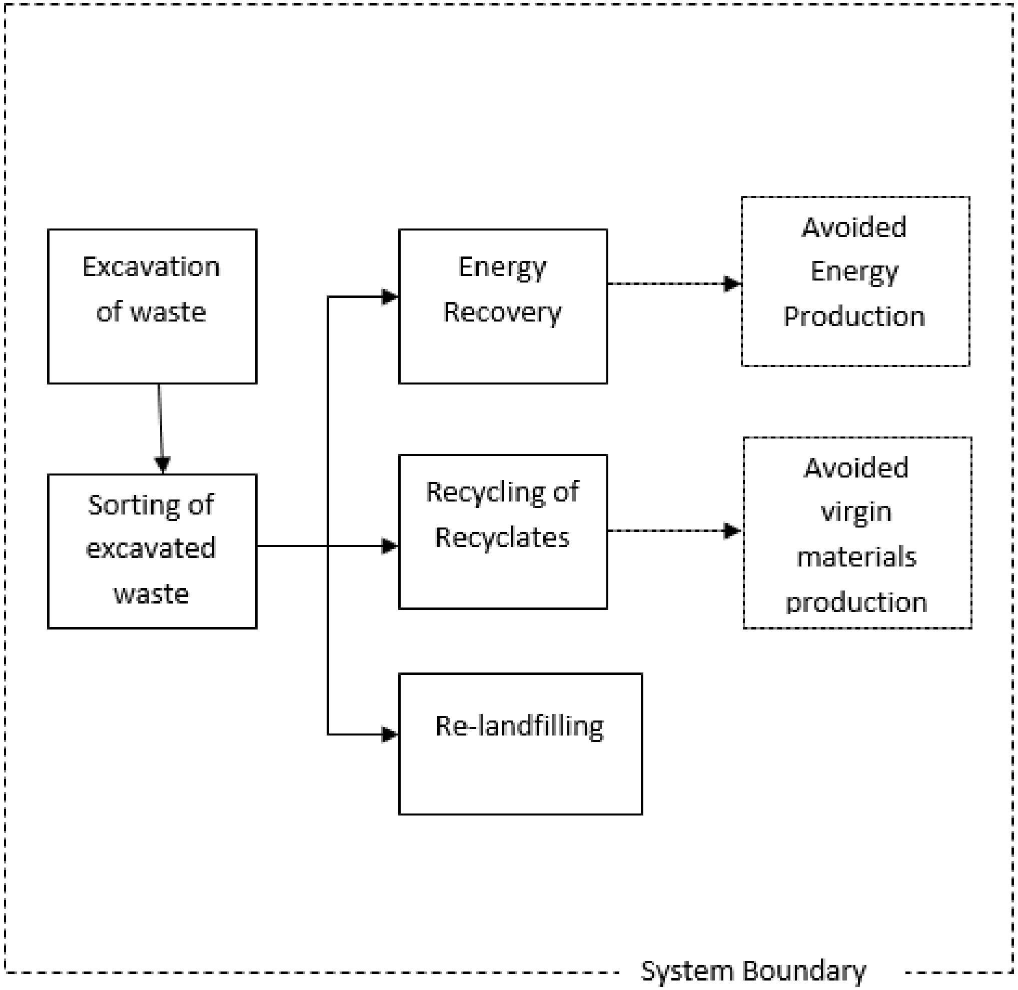
# Motivation for the study

- **General background**
  - Growing interest for landfill mining
  - Extending life time of landfill site
  - Scarce experience on technologies and performance
  - Large variations in landfill contents
- **Why LCA?**
  - A systematic assessment methodology
  - Estimates resource and environmental impact benefits in a systemwide perspective
  - More and more used for policy development
  - Able to highlight processes and parameters of key importance

# Goals of the project

- **Analyze the potential** environmental benefits of landfill mining when compared to no such mining
- **Review** existing landfill mining technologies and it's limitations

# Scope and design

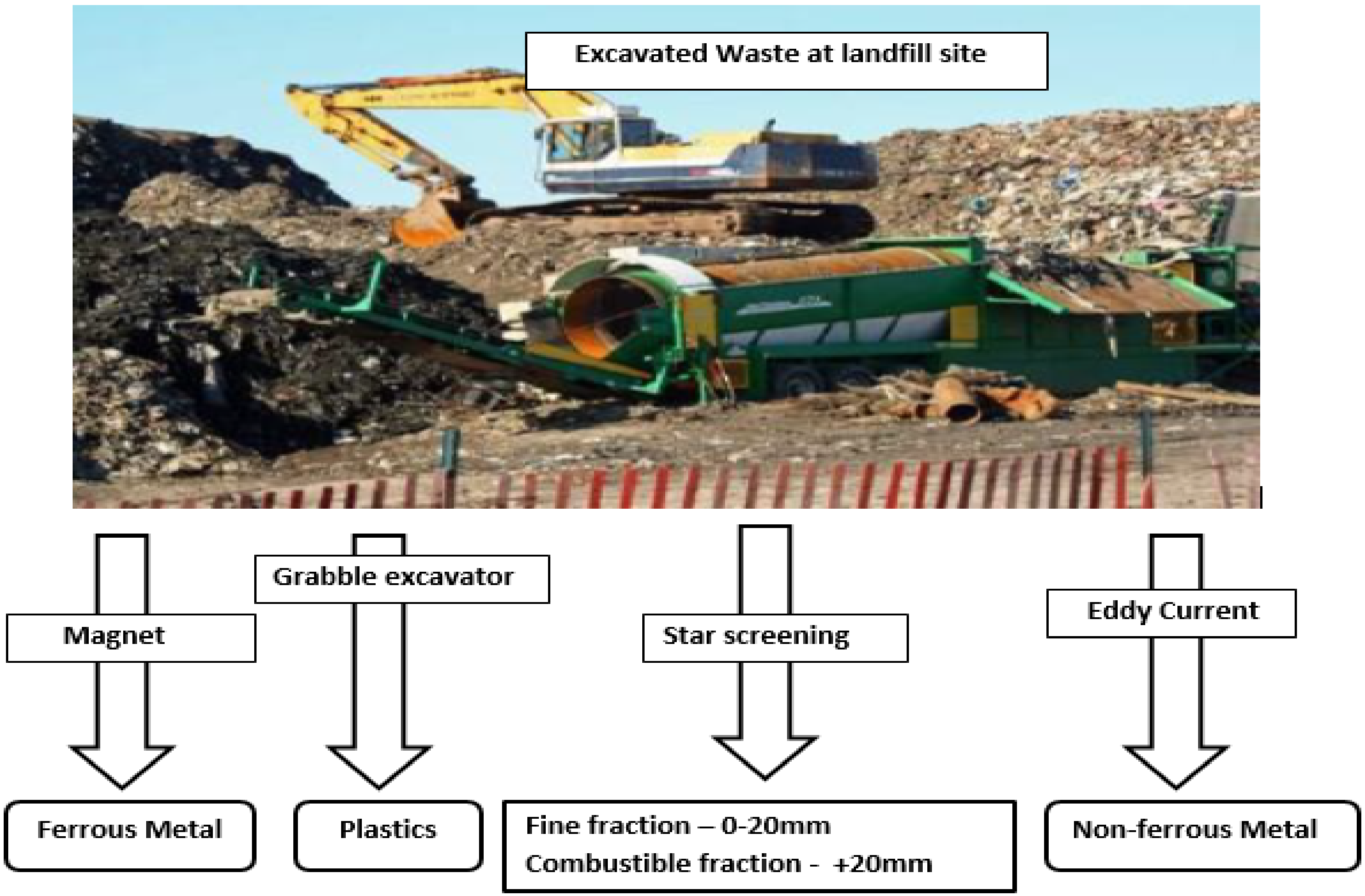



- **Reference flow =** Treatment of 1000kg of excavated waste from cell 2.1.2.2 in AV Miljø landfill
- **Impact categories =**
  - Global warming
  - Terrestrial eutrophication
  - Terrestrial acidification
  - Freshwater eutrophication
  - Marine eutrophication
  - Human toxicity
  - Eco-toxicity
  - Resource depletion
- Modelled in **EASETECH**

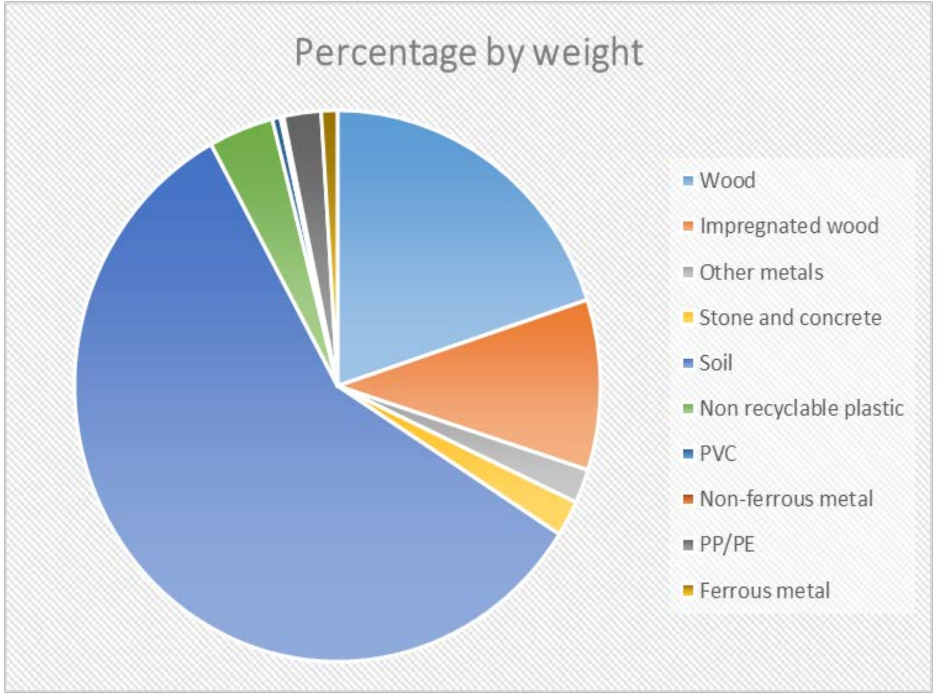
# Scenarios examined

| Scenario Name | Short description |
| --- | --- |
| Scenario 1 | Baseline Scenario – Do nothing scenario |
| Scenario 2 | Recovery of metals and combustible fraction, residues are re-landfilled |
| Scenario 3 | Recovery of Ferrous and non-ferrous metals, plastics and residues mainly soil are re-landfilled |

# Inventory - Sorting process



# Site specific data




| Material Fraction | % by weight |
|---|---|
| **Wood** | 19.94 |
| **Impregnated wood** | 10.00 |
| **Other metals** | 2.00 |
| **Stone and concrete** | 2.10 |
| **Soil** | 57.98 |
| **Non-recyclable plastic** | 3.99 |
| **PVC** | 0.50 |
| **Non-ferrous metal** | 0.20 |
| **PP/PE** | 2.30 |
| **Ferrous metal** | 1.00 |

# Site specific data

- 5% of repair done before re-landfilling
- Leachate collection efficiency 99.9%
- Fuel consumption during excavation and sorting

| Name and model of equipment | Fuel consumption in litres/ton total wet weight |
|---|---|
| Excavator A | 0.756 l/ton |
| Excavator B | 0.519 l/ton |
| Excavator C | 0.302 l/ton |
| Dumper | 0.564 l/ton |
| Sieve with generator | 0.384 l/ton |
| Crusher | 0.460 l/ton |

# Non-specific site data

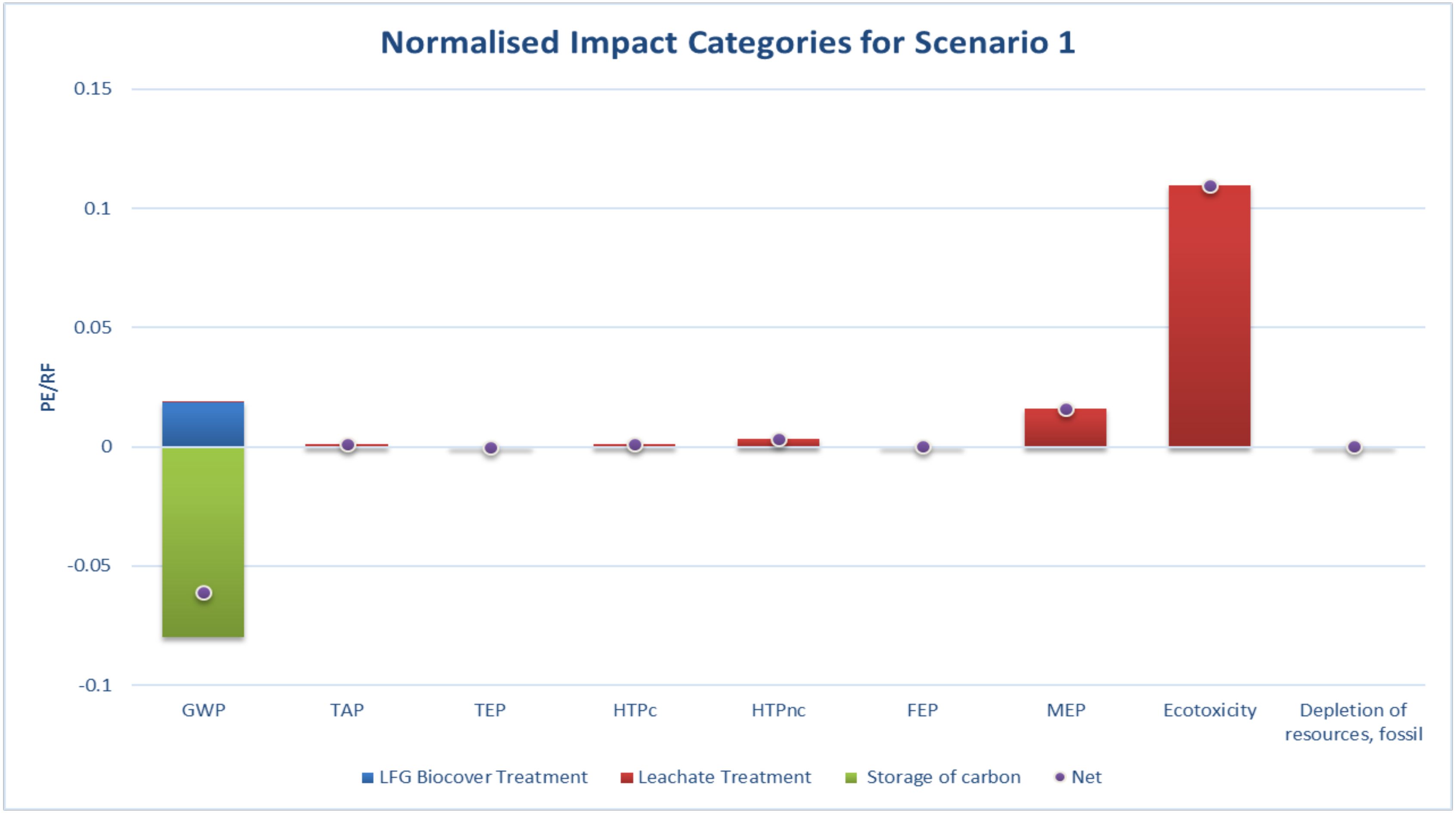
- Data
  - The Biofilter efficiency is 86% (Pedersen, Scheutz, & Kjeldsen, 2012)
  - ARC incineration plant 2020 process exchange data and energy recovery efficiency
  - Substitution ratio of all recyclables – plastics and metal
- Limitations:
  - Lack of data on physiochemical properties of the fine and combustible fraction
  - Lack of data on the quality of materials recovered
  - Lack of information on the amount of gas leaked during excavation

# LCA grouped processes

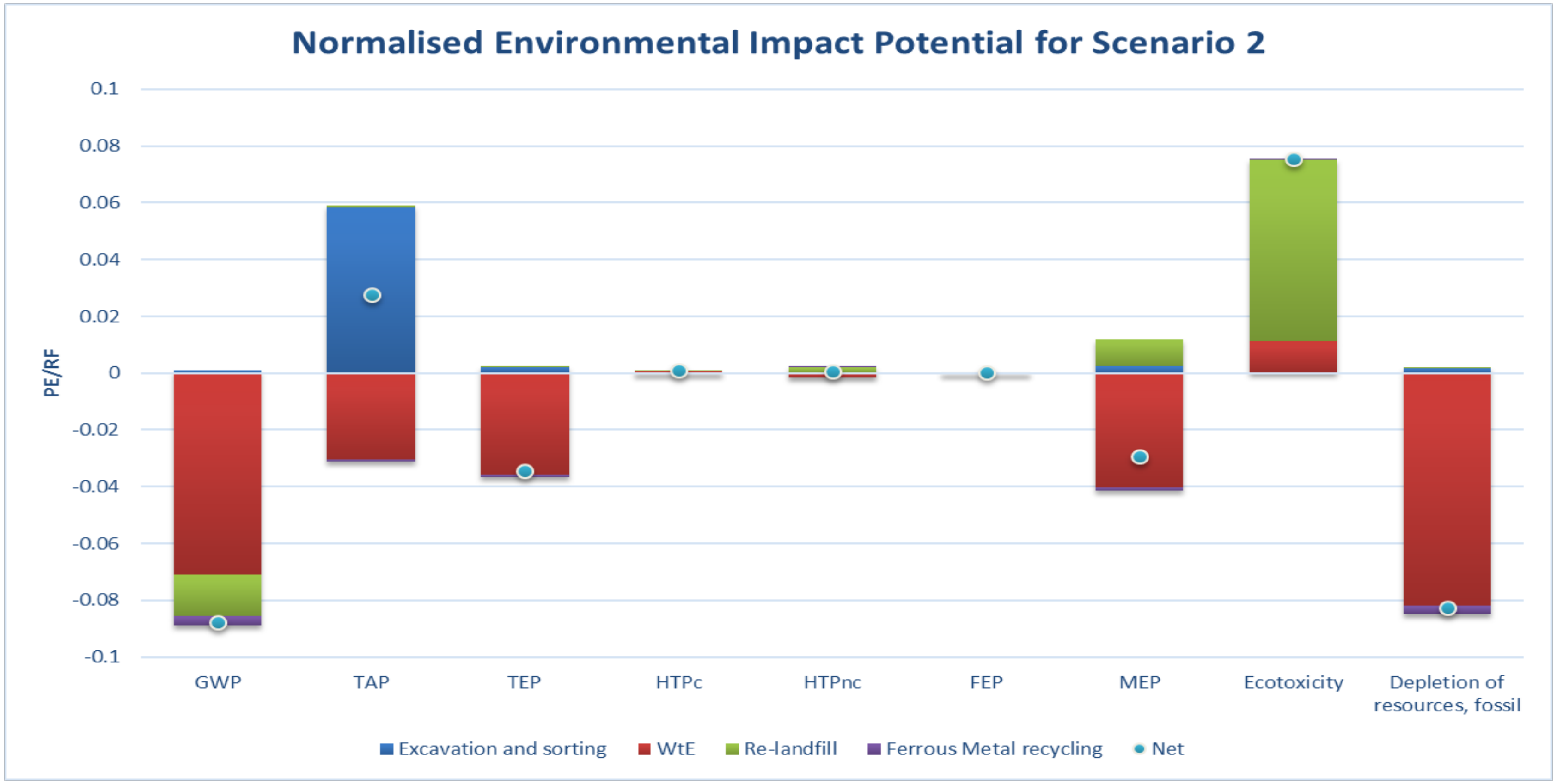
| Grouped Processes | What is composes of |
| --- | --- |
| LFG Biocover Treatment | LFG collection and treatment with biocover |
| Leachate Treatment | Leachate collection and treatment at WWTP Avedore |
| Storage of carbon | residual organic waste in the landfill |

| Grouped Processes | What is composes of |
| --- | --- |
| Excavation and sorting | Vehicle/Equipment used for excavation and sorting |
| WtE | Transport to incineration plant, WtE capital goods, fly ash utilization, metal recycling facility – steel and Al scrap, inert landfill, bottom-ash utilization |
| PVC recycling | Transport to PVC recycle facility, PVC recycle plant plus capital goods |
| PP recycling | Transport to PP recycle facility, PP recycle plant plus capital goods |
| Ferrous Metal recycling | Transport to steel recycle facility, steel recycle plant plus capital goods |
| Non-Ferrous Metal recycling | Transport to aluminium recycle facility, aluminium recycling plant plus capital goods |
| Re-landfill | Re-landfilling of residues, collection and treatment of leachate, collection and treatment of landfill gas and carbon storage. |

# Scenario 1 contribution analysis



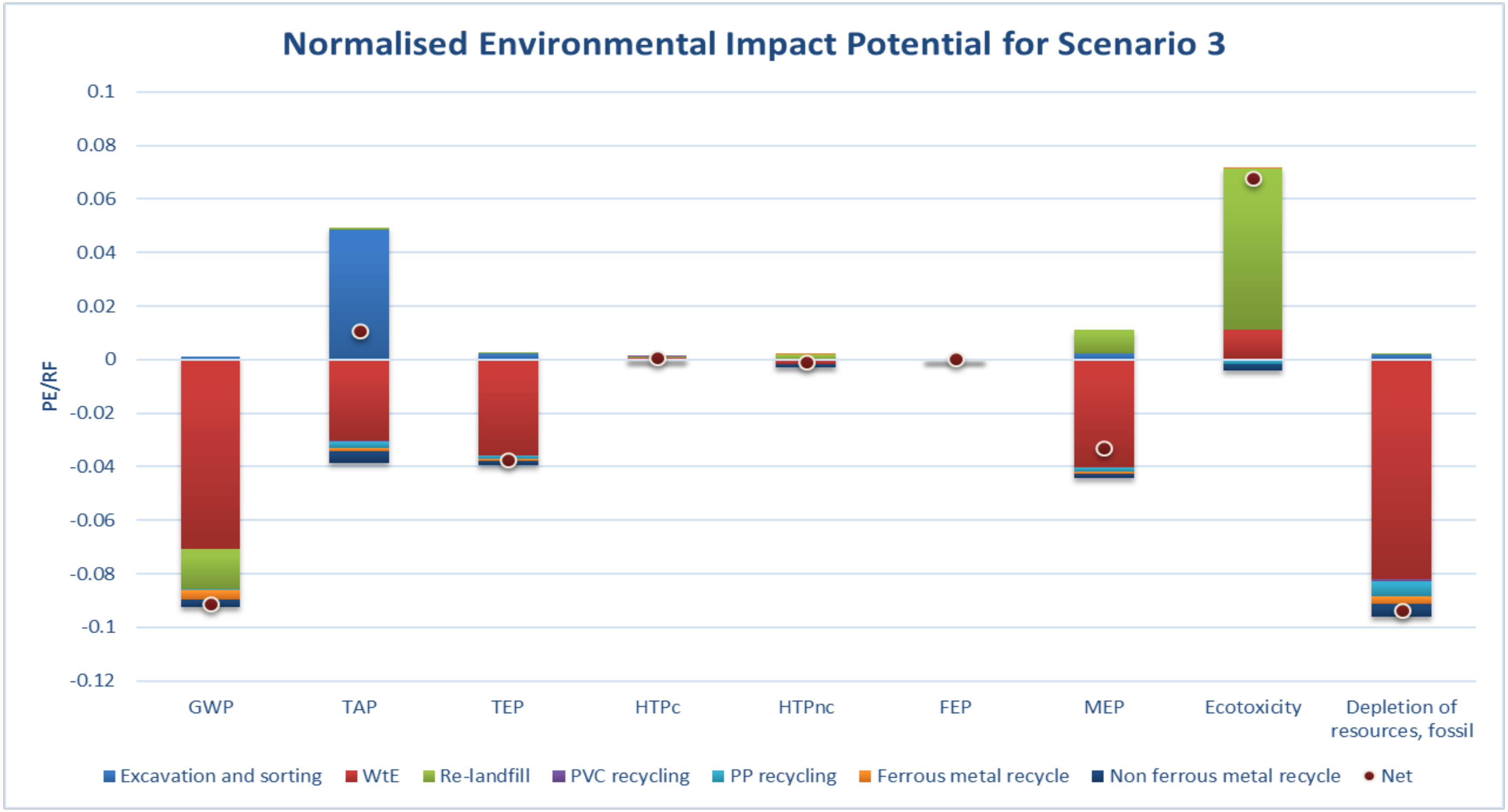
# Scenario 2 contributions analysis



# Scenario 2 contributions analysis

| Impact Category | Most contributing process | Most contributing substance |
| --- | --- | --- |
| **GWP** | Savings from WtE and re-landfilling of waste | CO2 and methane |
| **TAP** | Impact from Excavation and sorting and savings from WtE | SO2 |
| **TEP** | Savings from WtE | NOx and Ammonia |
| **HTPc** | Impact from WWTP | Chromium VI and Arsenic |
| **HTPnc** | Impact from WWTP | Arsenic and Zinc |
| **FEP** | Re-landfilling | Phosphate |
| **MEP** | Savings from WtE and impact from re-landfilling | NOx and Ammonia |
| **Ecotoxicity** | Impact from Re-landfilling | Zinc and Zinc ion |
| **Depletion of resources, fossil** | Savings from WtE | Coal and oil |

# Scenario 3 contributions analysis



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| **HTPnc** | Savings from WtE, PVC and PP | Arsenic and Mercury |
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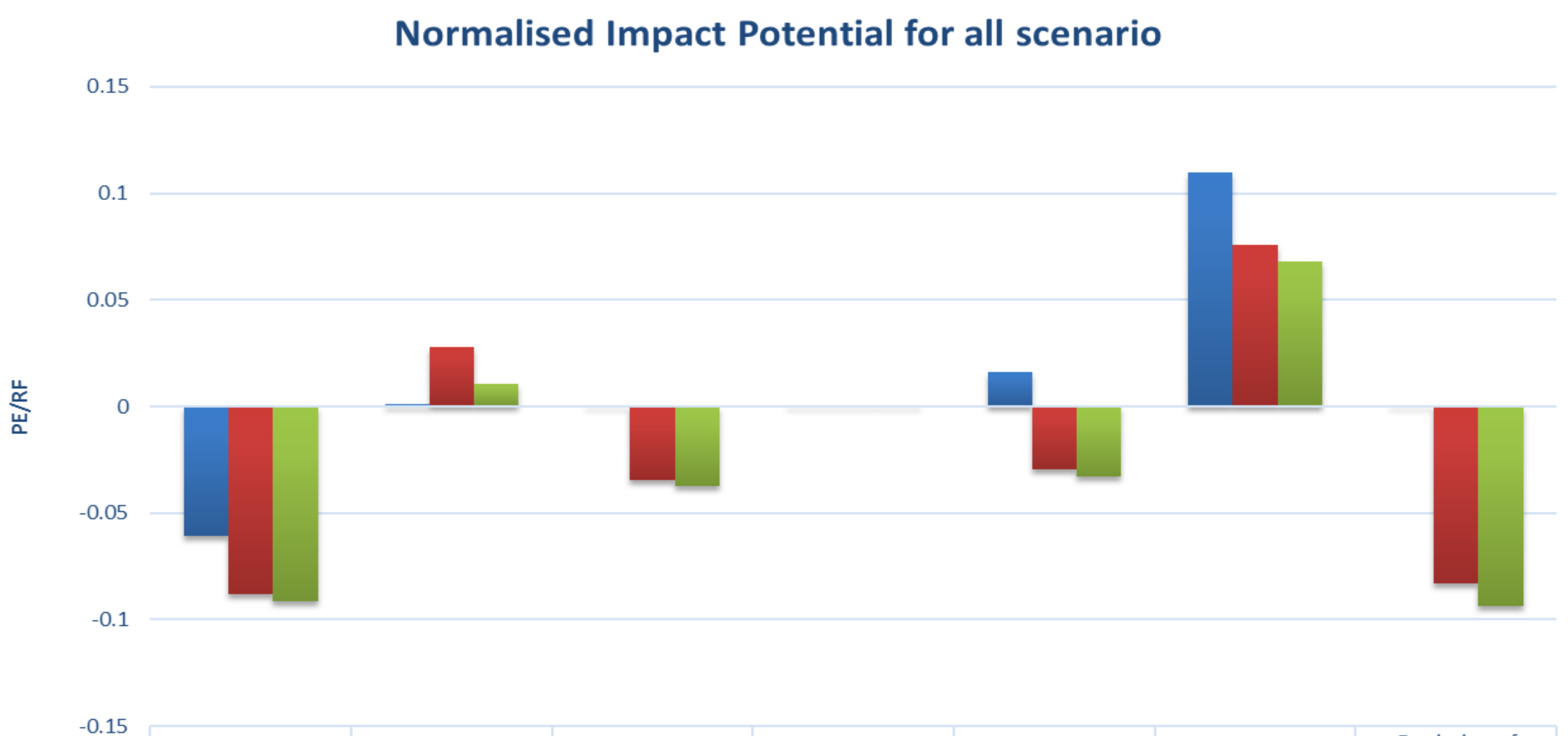
# Comparison of scenarios




| | GWP | TAP | TEP | FEP | MEP | Ecotoxicity | Depletion of resources, fossil |
|---|---|---|---|---|---|---|---|
| Scenario 1 | -0.0609047 | 0.00116 | 0.00004786 | 0.0004745 | 0.01607 | 0.1098 | 0.0002235 |
| Scenario 2 | -0.08790277 | 0.02771589 | -0.034435317 | 0.000284395 | -0.029393487 | 0.075575889 | -0.082787662 |
| Scenario 3 | -0.091442231 | 0.010787266 | -0.037250128 | 0.000223036 | -0.033147293 | 0.067790041 | -0.093822801 |

# General finding

- Overall savings mainly due to energy recovery for scenario 2 and 3
- Minimal savings from plastic and metal recycling – 4% of entire waste mass
- S3 shows the best environmental performance in almost all impact category due to sorting and recycling of other materials like PVC, PP and nonferrous metal(Al)

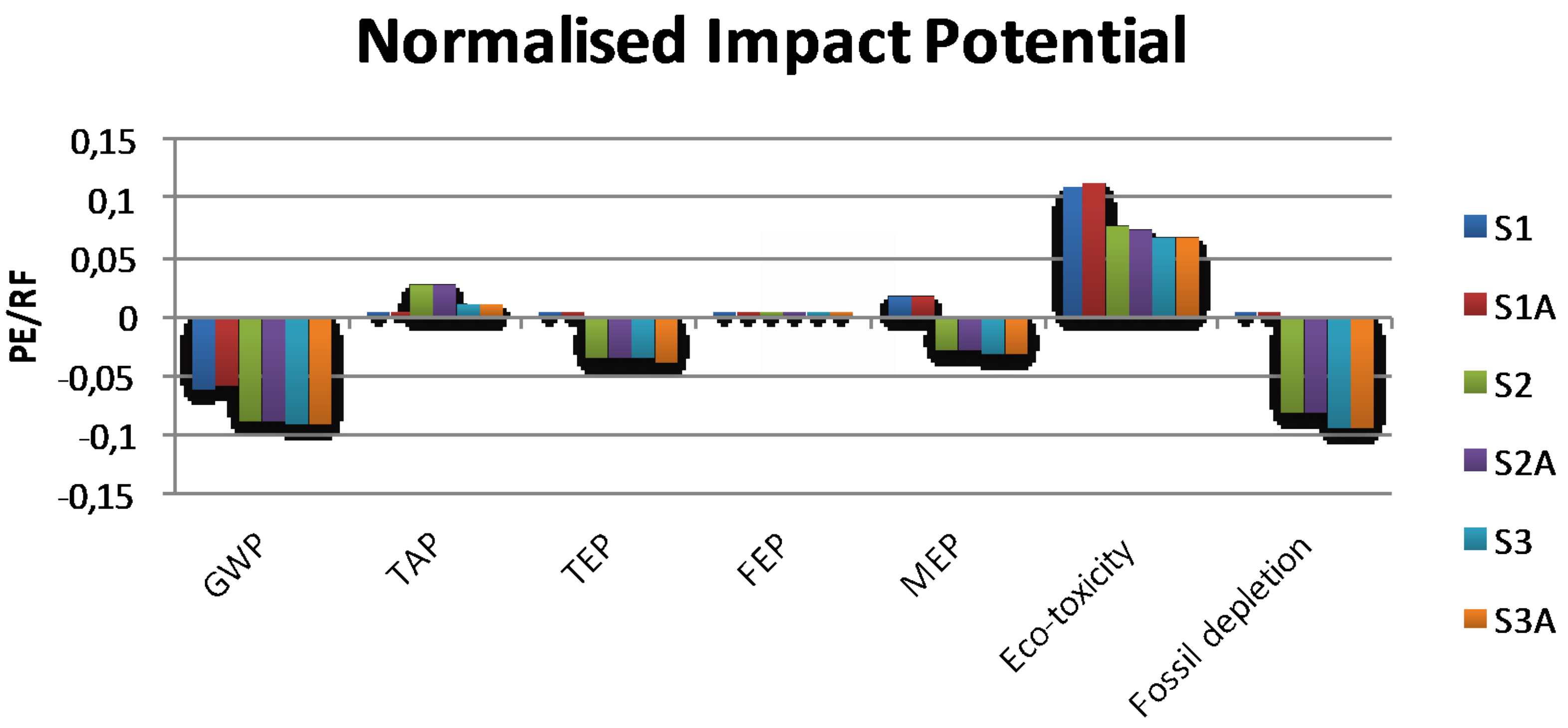
# Sensitivity analysis

- **Perturbation Analysis:**
  - Incrementing key parameters “One-at-a-time” to assess the sensitivity of the model
- **Scenario Analysis:**
  - Comparing similar scenarios modifying only one process and analyze the differences in the final impact

# Perturbation analysis

- **Key parameters S2**:
  - Electricity recovery from Waste-to-Energy
  - Heat recovery from Waste to Energy
  - Biocover efficiency
  - Fuel consumption by excavator
- **Key parameters S3:**
  - Electricity recovery from Waste-to-Energy
  - Heat recovery from Waste to Energy
  - Biocover efficiency
  - Fuel consumption by excavator
  - Substitution ratios for polypropylene and nonferrous metal

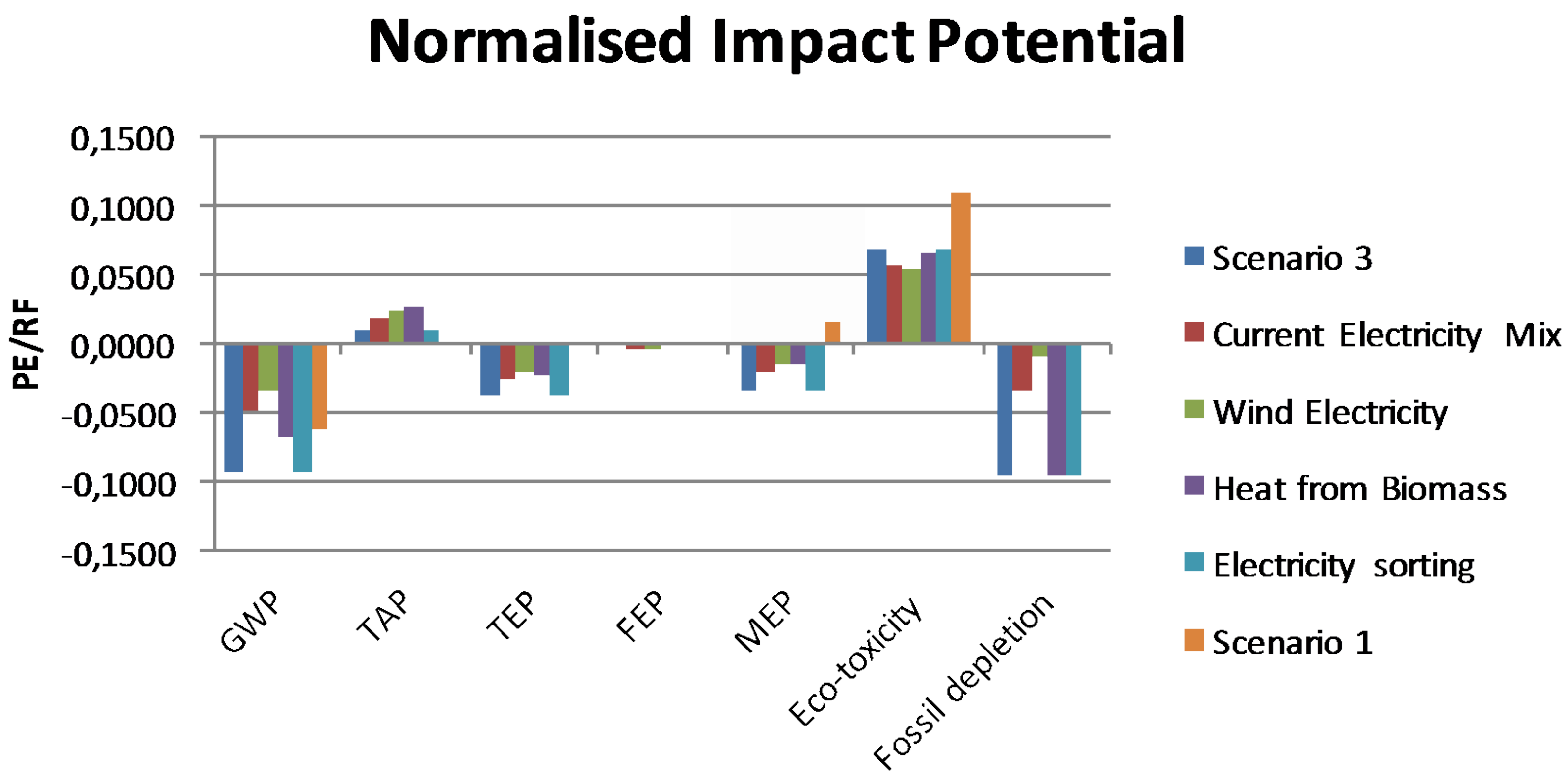
# Scenario Analysis 1
## Construction of new landfill




S1A – scenario 1 + environmental impact from setting up new landfill
S2A – scenario 2 + savings from removing 41% of waste from the landfill
S3A – scenario 3 + savings from removing 44% of waste from the landfill

# Scenario Analysis 2

## Marginal Electricity Used



# Uncertainties

- Substitution ratio for the recovered plastics is yet to be defined due to the poor quality of the plastics
- Default data have been implemented to model most of the disposal and treatment technologies
- No information about the physiochemical properties of the excavated waste

# Conclusions

- Scenario 3 performed best in most impact categories
- Contribution analysis show that waste to energy is the most contributing process
- Recovering and recycling the majority of the excavated waste is important, as this elongates the life span of the landfill
- The perturbation analysis confirmed the key influential parameters of the system:
  - electricity and heat recovery from WtE
  - aluminum and polypropylene substitution ratio
  - biocover efficiency
  - fuel consumption by excavators
- Waste to energy is a good option for the excavated waste treatment but focus should be drawn on the marginal electricity used as this influence results a lot

# Recommendation

- Investigations on the physiochemical property of the excavated waste are needed to enhance resource utilization and toxicity containment
- Study and improve on sorting and recovery of metals and plastics
- Identification of the possible uses of the fine fraction
- For future mining, proper investigation should be carried out to ensure successful mining
  - Target landfills with more metals and plastics.
- For landfill mining, targets should be on older landfills
  - Landfills that were active before the invent on the EU waste directives – 3Rs ( recover, recycle and reuse)
- Proper test should be carried out to ensure that there are no leaks of landfill gas which contributes to global warming.

# Thank you for your time