UNIKASSEL VERSITÄT | BAUINGENIEUR UND UMWELT INGENIEURWESEN

Critical factors for landfill mining

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LANDSS landfill aftercare forum

March 20th 2019, Birmingham

What turns landfilled materials into resources?

'It's a big, expensive and risky project,' says James Howells, from Newport

Source: Indenpendent, accessed on 08.12.2017

Content

- Introduction
  - Historical development & background
  - Landfills as anthropogenic resources: MINEA
  - Landfill mining in theory & practice
- What drives the economy of landfill mining?
  - Goal & Scope
  - Modeling approach
  - Results & Discussion
- Summary
  - Critical factors for the economy of landfill mining

Introduction

- No commonly accepted definition
  - … excavate, process, recycle and treat previously deposited materials
- 500,000 (or so) landfills in Europe, which require post-closure management
  - Landfill mining as an alternative
- Overall research trends
  - From solving local landfill problems to emphasis on resource recovery
  - From simple mobile equipment to more technically advanced solutions
  - An emerging system perspective – societal impacts and synergies

Recent developments: Enhanced landfill mining

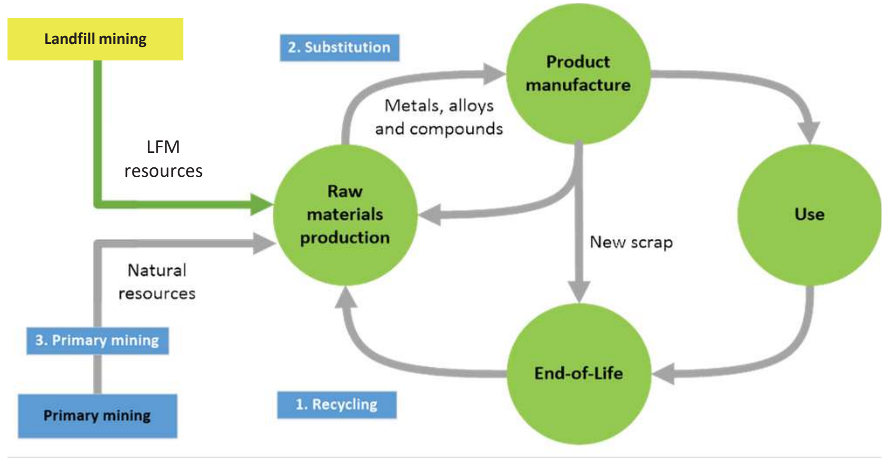
Source:
http://www.elfm.eu/en

… combining remediation with recovery of deposited materials, energy carriers and land resources

Landfill mining from a circular economy perspective

- A stepping stone for building future capacity for a circular economy
  - In many regions, an exploitation of landfills could double the available amounts of some secondary resources for decades

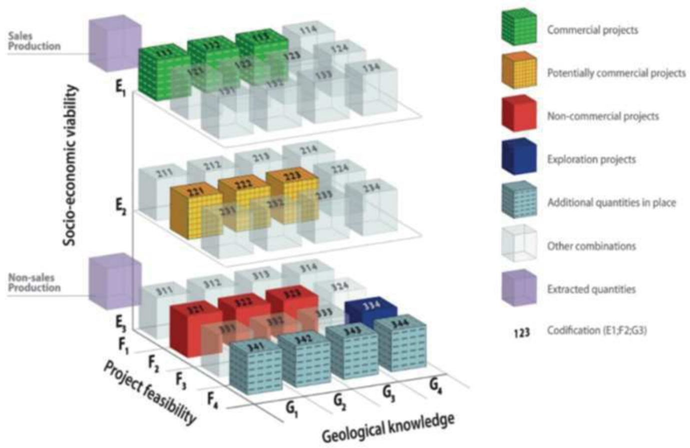
- A possible seed-bed for development of new, more resource-effective separation and recycling technologies



- What share of anthropogenic materials can be designated as a resource?

  - Availability of secondary raw materials from anthropogenic sources such as **landfills**, mine tailings, buildings, infrastructure, etc.

  - Classification in line with geological resource classifications



MINEA – WG 2.2 „Resources in landfills“

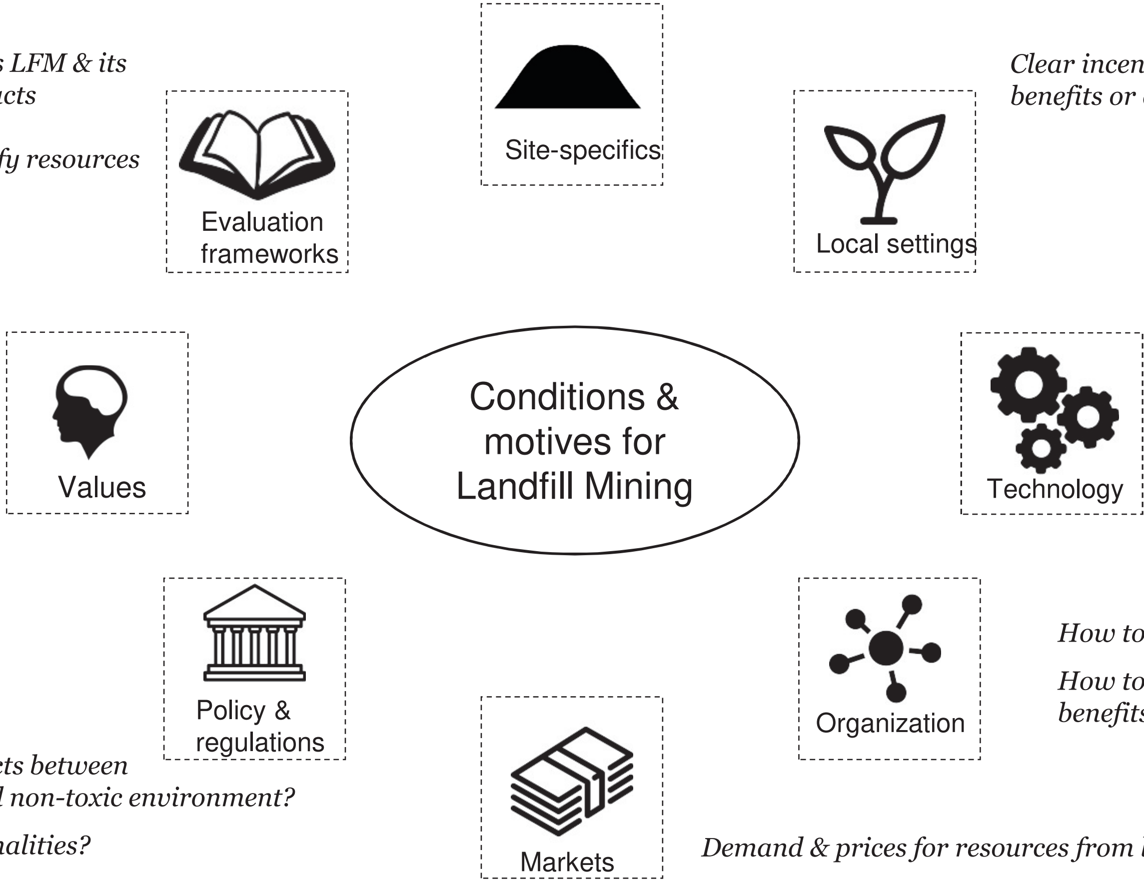
Working group leader: Joakim Krook

Which landfills are most suitable for LFM? Based on what?

How to assess LFM & its multiple impacts

How to classify resources in landfills?

Clear incentives rely on indirect benefits or avoided alternative costs



Cost & Benefits

To whom?

What can be recovered and at what quality level? Now and in the years to come…

How to best organize such projects?

How to distribute costs and benefits among different actors?

How to handle conflicts between circular economy and non-toxic environment?

Environmental externalities?

Demand & prices for resources from landfills?

Waste markets based on gate-fees and disposal costs

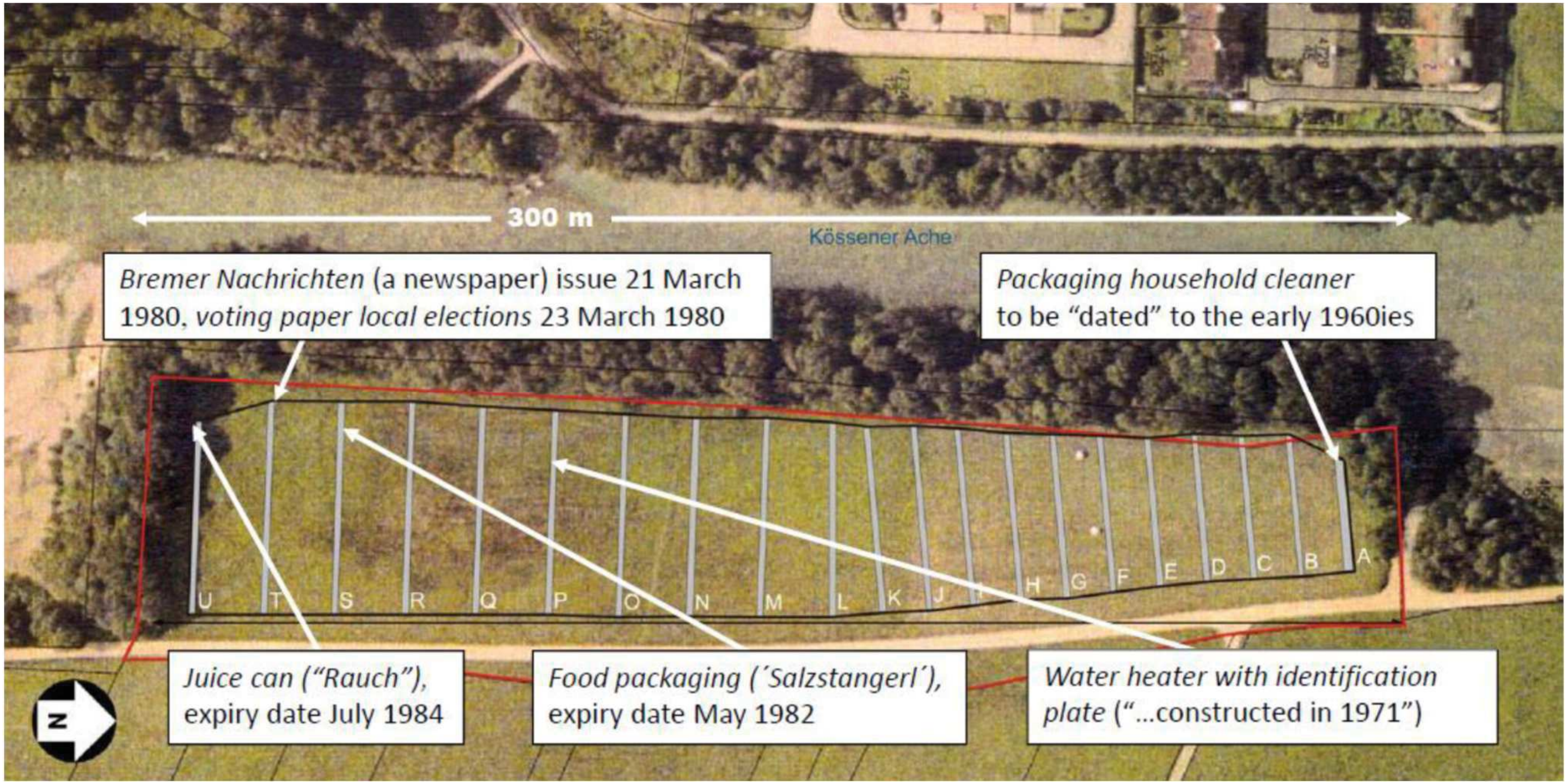
LFM in practice: former dumpsite in Kössen

Motivation:

Site heavily affected by flooding & area required for flood protection measures

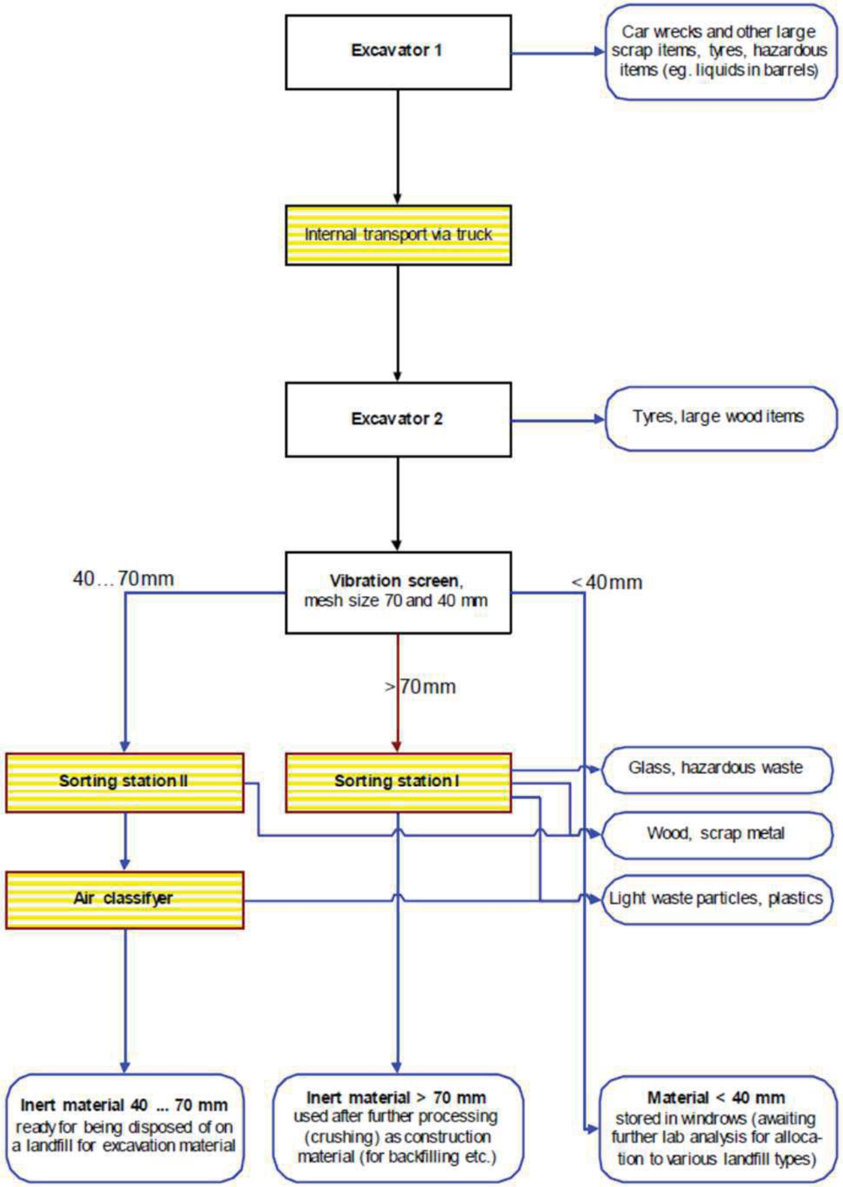
Mining period:

07/2014 – 06/2015



Source: Steiner (2015): Waste-to-Resources conference.

LFM in practice: Excavation & sorting at Kössen site

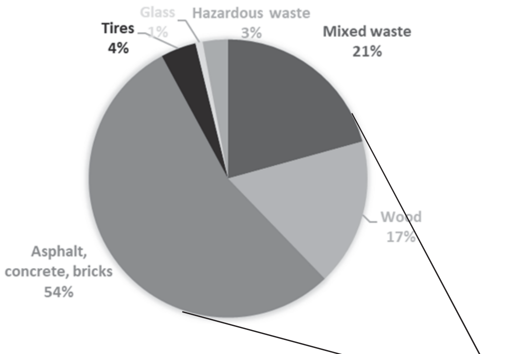


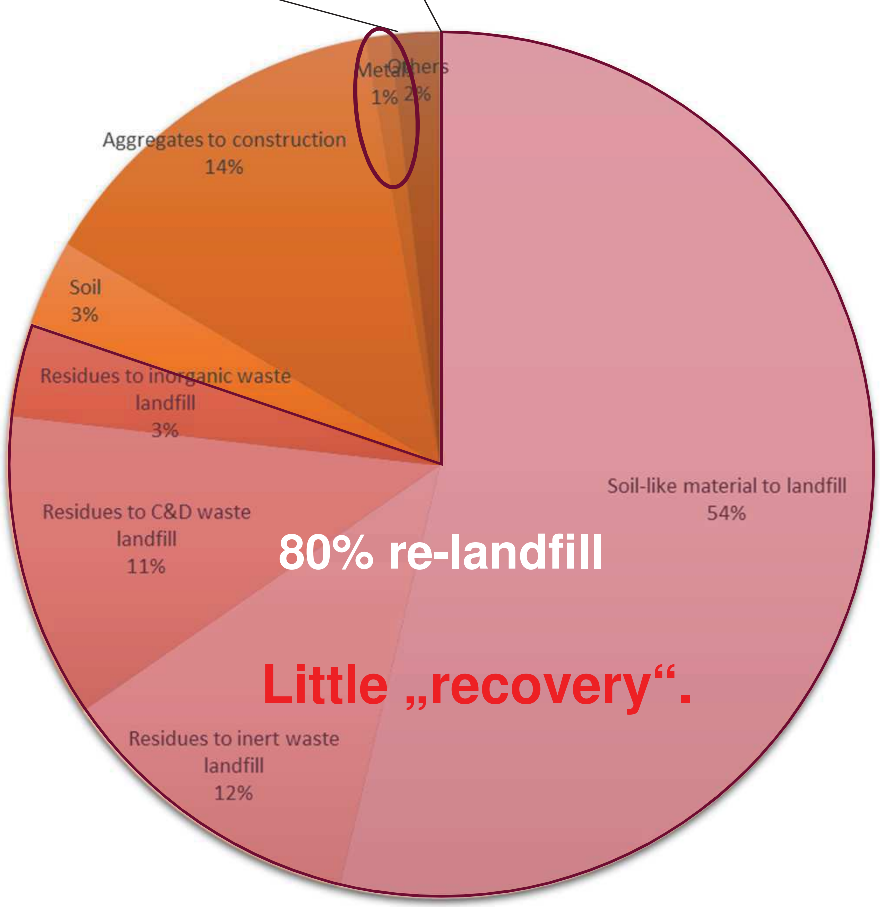
Simple technology.

Source: Steiner (2015): Waste-to-Resources conference.

LFM in practice: Output materials

Source: TBU (2016): Räumung der Altablagerung „Auwirtslacke“





LFM in practice: Economy of the Kössen project

- Project economy

Total costs:	1.5 Million Euro
Total revenues:	90,000 Euro
Net result:	-1.4 Million Euro

→ Specific costs of 17,5 Euro per ton of deposited waste
→ Specific costs of 100 Euro per m² of reclaimed land

Material recovery (alone) does not justify the LFM project….

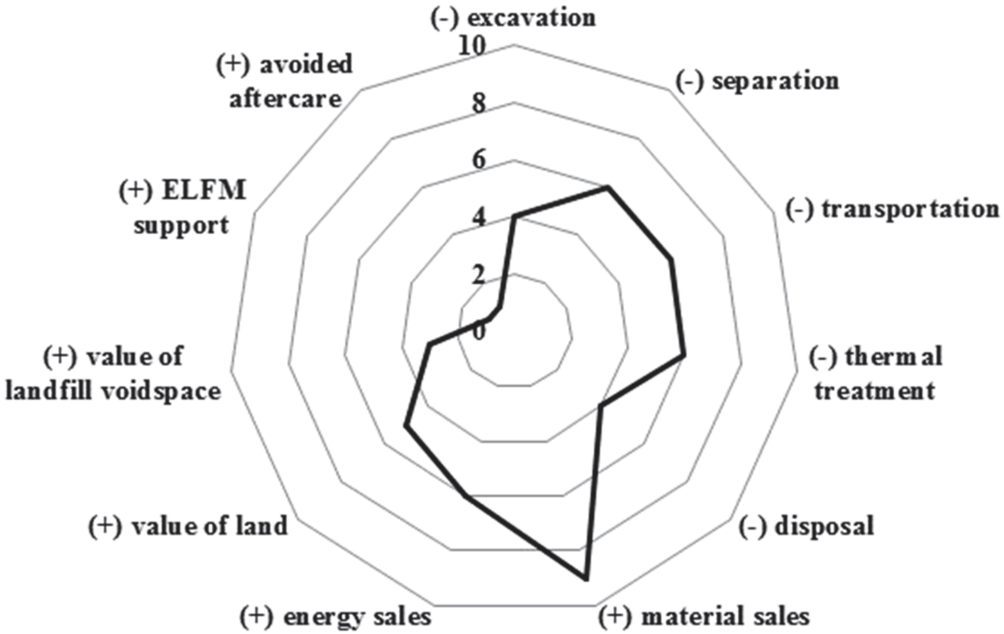
Poor economy.

Source: TBU (2016): Räumung der Altablagerung „Auwirtslacke"

Landfill mining in theory: review of economic assessments

- 10 recent case studies in peer reviewed journals
  - different regions, project sizes, objectives and complexities

- Reported hot-spots in terms of main costs (-) and benefits (+) in the reviewed assessments



Krook et al. (2018): Science to support circular economy symposium

Landfill mining in theory: methodological issues

SCENARIO LEVEL

Studied landfills
- Low-grade MSW
- Low reference costs

Analytical concerns
- Implications of site-specifics?

Employed processing schemes
- From simple to advanced technologies
- Often only one processing line/scenario

Analytical concerns
- Selection criteria? Alternatives?
- Processes treated as black boxes

Assumptions of marketability
- Exhumed resources salable
- Full substitution

Analytical concerns
- Implications of marketability constraints?

Exploration → Excavation → Separation → Treatment & Recovery → WtE, WtM & Disposal

Specificness and quality of applied data

High/Moderate — Low →

PARAMETER LEVEL

Main origin of data
- Adjacent knowledge fields, industry estimates & small-scale trials

Analytical concerns
- Applicability of high separation and recovery efficiencies?

Handling of data uncertainties
- Mainly input parameters as single estimated values

Analytical concerns
- Implications on performance of stochastic variations & epistemological uncertainties?

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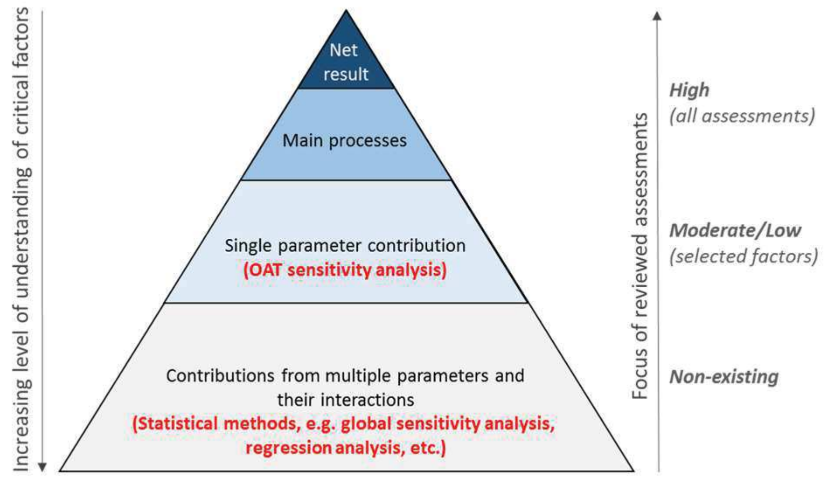
Landfill mining in theory: validity and uncertainty of results

- Recent assessments target deterministic results on economic feasibility
  - Net outcome for a specific scenario
  - Provide little knowledge on what builds up performance of landfill mining



- Ignoring scenario & data uncertainties provide simplified results, but are they valid and useful?
  - High implicit uncertainties
  - Miss out potentials for improvement
  - Difficult to identify critical factors

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Systematic assessment of critical factors for the economic performance of landfill mining in Europe

by members of the MINEA working group 2.2

David Laner, John Laurence Esguerra, Joakim Krook, Mika Horttanainen, Mait Kripsalu, Rene Moller Rosendahl, and Nemanja Stanisavljevic

Manuscript submitted to Waste Management

- **Goal:**

  Assess generically important factors for the business case of landfill mining in consideration of regional differences within Europe

  → Analyse under what specific conditions and settings landfill mining could be economically justified and identify key economic drivers in these cases

- **Scope:**

  The spatial and temporal scope of the study involves MSW landfills in Europe with current regional variations in price settings and waste management and treatment practices.

Modeling approach

Factors & Data sets

Factor			
F0: Variation in excavation & sorting costs	0-1	0-2	0-3
F1: Landfill settings	1-1	1-2	1-3
F2: Landfill composition	2-1	2-2	2-3
F3: Reference scenario	3-1	3-2	3-3
F4: Project drivers	4-1	4-2	4-3
F5: Excavation & sorting technology	5-1	5-2	5-3
F6: Waste-to-Energy	6-1	6-2	6-3
F7: Markets for materials and energy	7-1	7-2	7-3
F8: Value of recovered land or void space	8-1	8-2	8-3
F9: Disposal and transport costs	9-1	9-2	9-3
F10: Transport distances	10-1	10-2	10-3
F11: Financial accounting	11-1	11-2	11-3

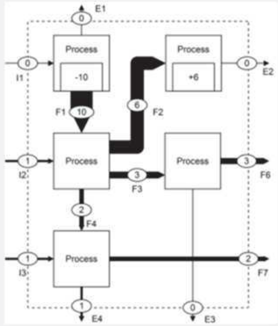
12 factors with
3 alternative sets

3^{12} combinations = 531,441 combinations

Economic model

1 Mg waste excavated

Physical flow model



Evaluation of of costs and revenues (Discounted cash flow analysis)

Net present value [€/Mg]
- Project total
- Selected cost and revenue items

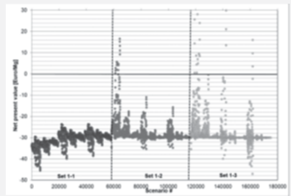
Scenarios

Scenario **1**
(1-1,2-1,3-1,4-1,5-1,6-1,
7-1,8-1,9-1,10-1,11-1)

Scenario **2**
(1-1,2-1,3-1,4-1,5-1,6-1,
7-1,8-1,9-1,10-1,11-2)

.
.
.

Scenario **531,441**
(0-3,1-3,2-3,3-3,4-3,5-3,
6-3,7-3,8-3,9-3,10-3,11-3)



Global sensitivity analysis
→ critical factors for economic performance

Selected factors and datasets

#	Level	Description	Set 1	Set 2	Set 3
F0	System	Regional variations in excavation & sorting costs (investment, labour and maintenance)	Low	Medium	High
F1	Site/Project	Landfill settings	Small-scale landfill, short project duration	Medium-scale landfill, medium project duration	Large-scale landfill, long project duration
F2	Site	Landfill composition	Rich MSW landfill	Average MSW landfill	Poor MSW landfill
F3	Site/System	Reference scenario	Do nothing	Medium intensity aftercare	High intensity aftercare or remediation
F4	Project	Project drivers	Resource recovery	Resource recovery & land reclamation	Resource recovery & void space recovery
F5	Project	Excavation & sorting technology	Mobile sorting (on-site)	Conventional tech. stationary sorting (off-site)	BAT stationary sorting (off-site)
F6	System	Waste-to-energy (WtE)	Low gate fee	Medium gate fee	High gate fee
F7	System	Markets for material and energy	Low-level prices	Medium-level prices	High-level prices
F8	Site/System	Value of reclaimed land or landfill void space	Low	Medium	High
F9	System	Waste treatment, disposal, and transport costs	Low	Medium	High
F10	System/Site	Transport distances	Short	Average	Long
F11	System	Financial accounting	Low risk	Medium risk	High risk

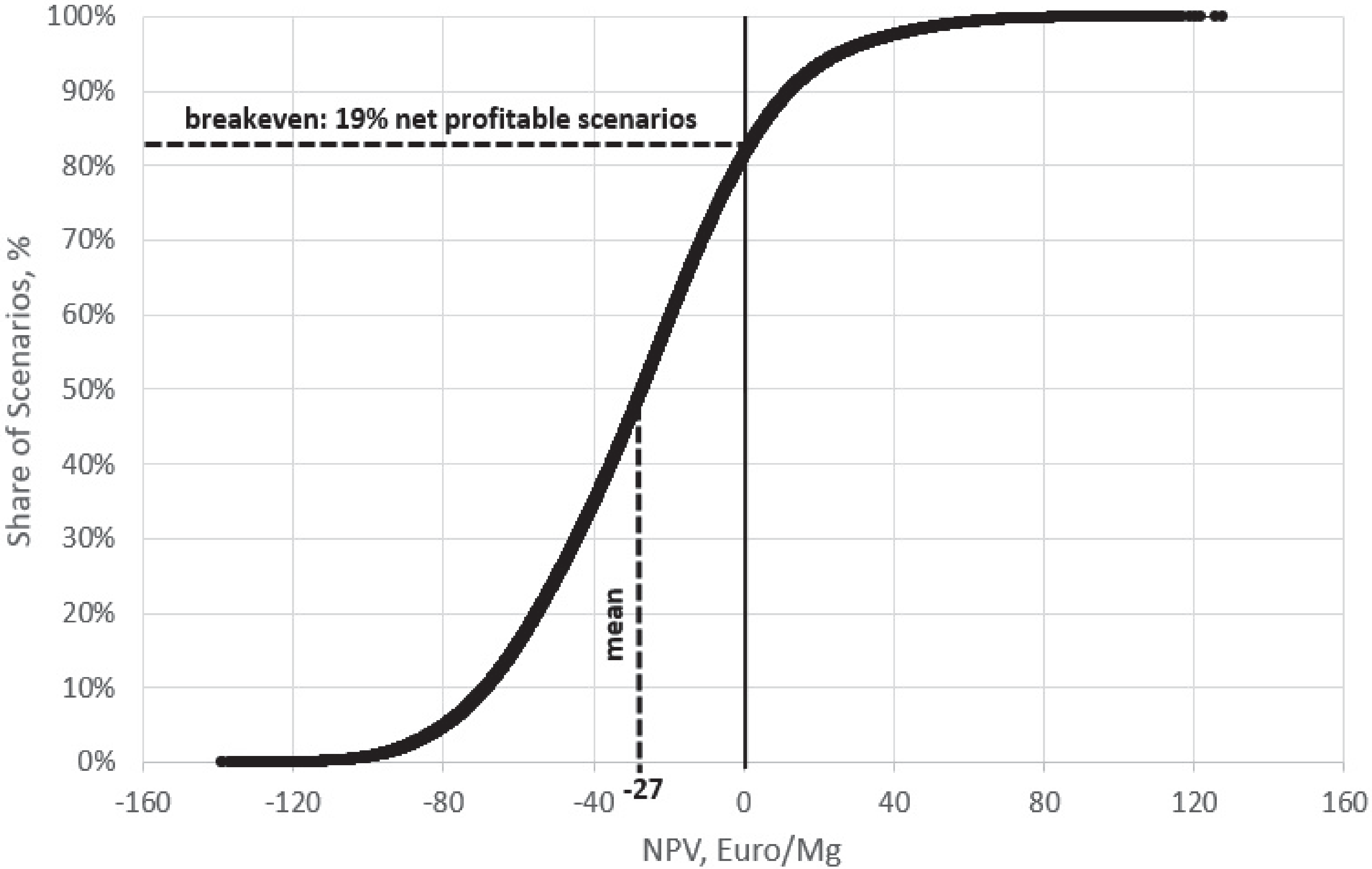
Regional archetypes

- Archetypal settings
  - Purpose: analyse the economy of landfill mining projects under specified boundary conditions (e.g. regional disparities)
  - Design: fix seven factors on the system level (F0, F3, F6, F7, F8, F9, F11) by choosing one of the three datasets

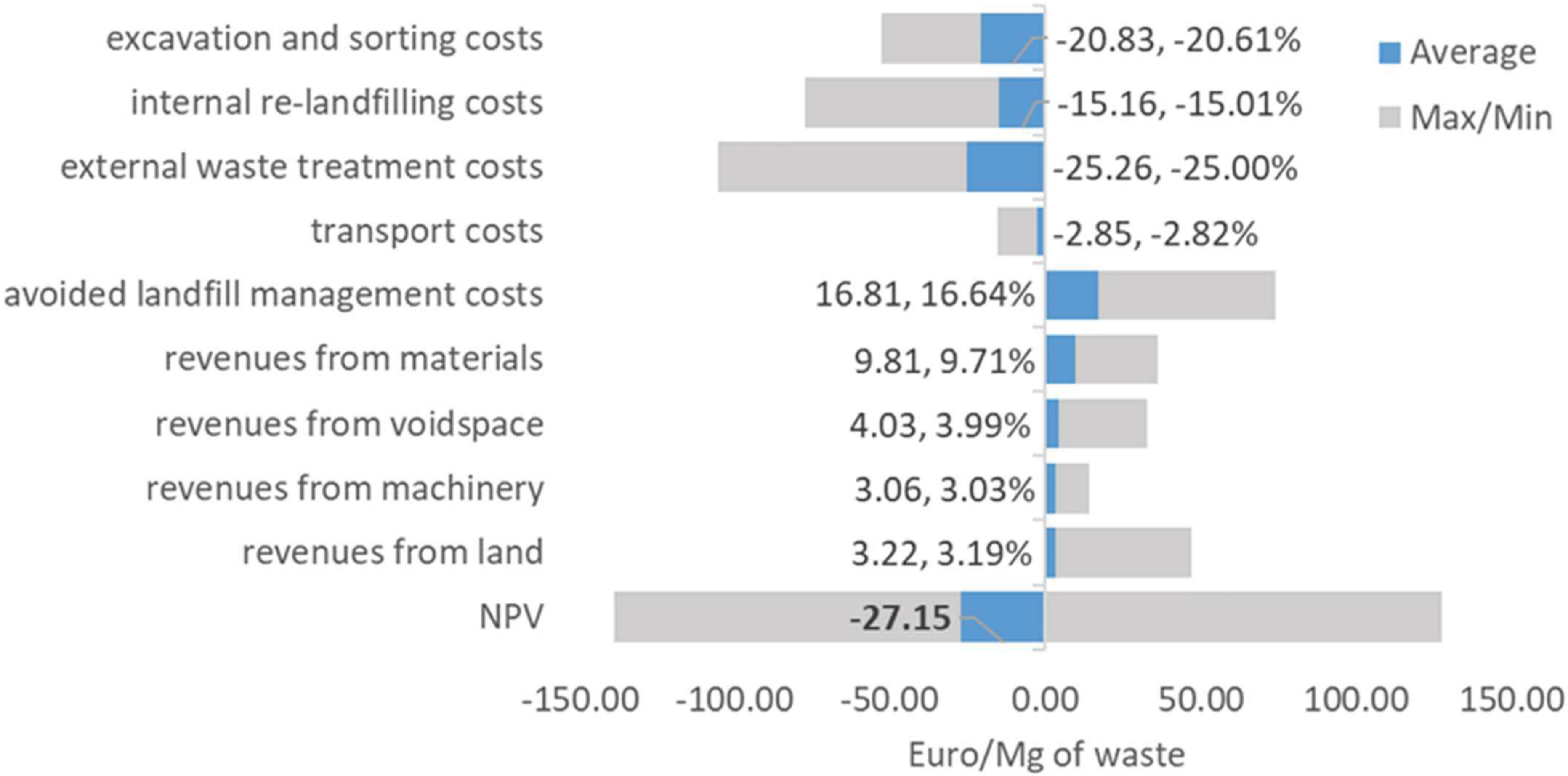
  → 243 scenarios (3^5= 243) for each setting

- Two extreme settings
  - High income, high waste management standards
    - F0-3, F3-3, F6-3, F7-3, F8-3, F9-3, F11-1
  - Low income, low waste management standards
    - F0-1, F3-1, F6-1, F7-1, F8-1, F9-1, F11-3

NPV of landfill mining scenarios



Present value of cost and revenue items



Sensitivity of project NPV to factor variation

- Variations in 4 factors explain >75% of the results‘ variation
  1. **F9** - Waste treatment and disposal costs: 34%
  2. **F3** - Reference scenario: 21%
  3. **F6** - Waste-to-Energy: 12%
  4. **F1** - Landfill settings: 10%

  Mainly direct effects of variation on results (F9, F3, F6)

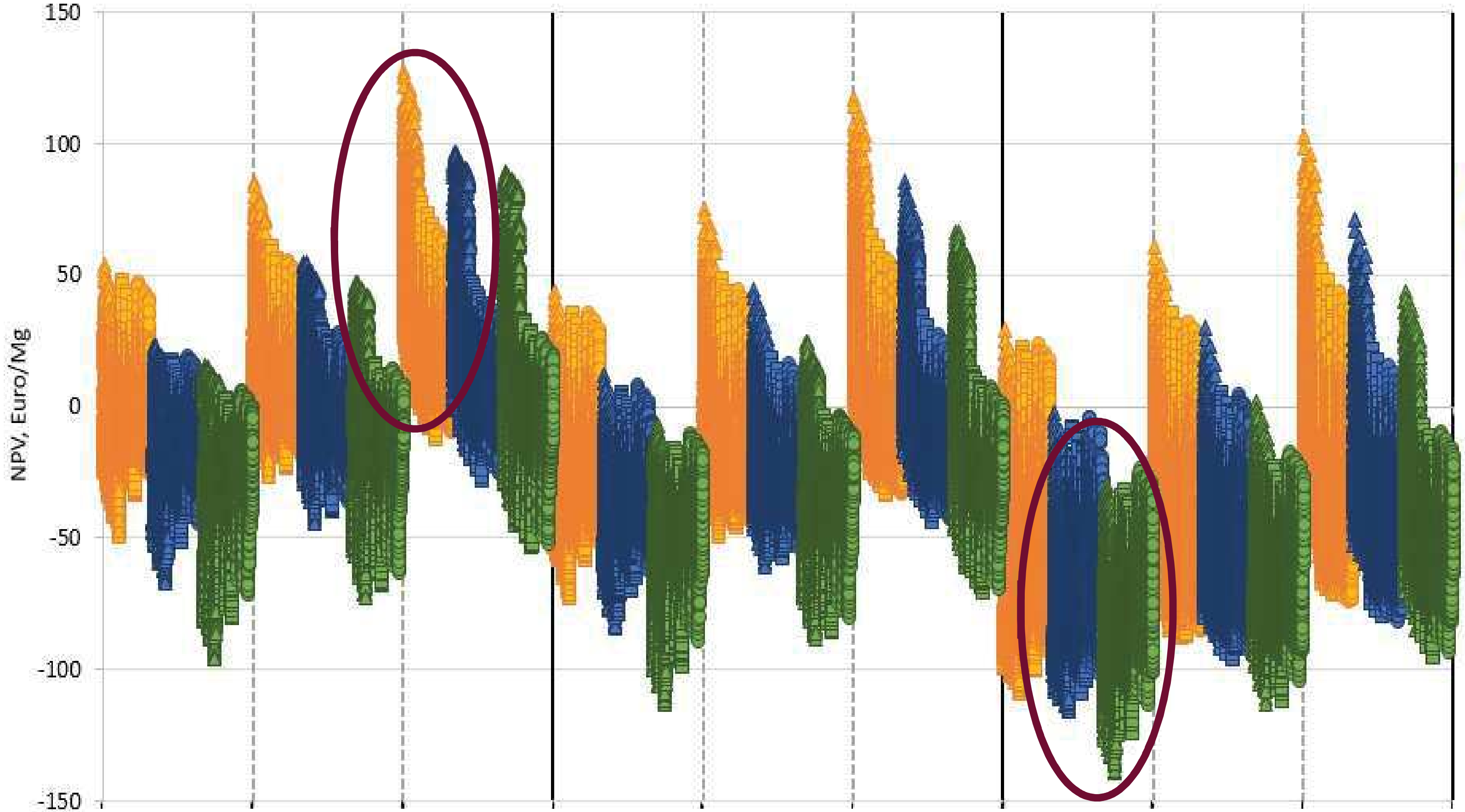
  Mainly indirect effects of variation on results (F1)

- Variation in other factors

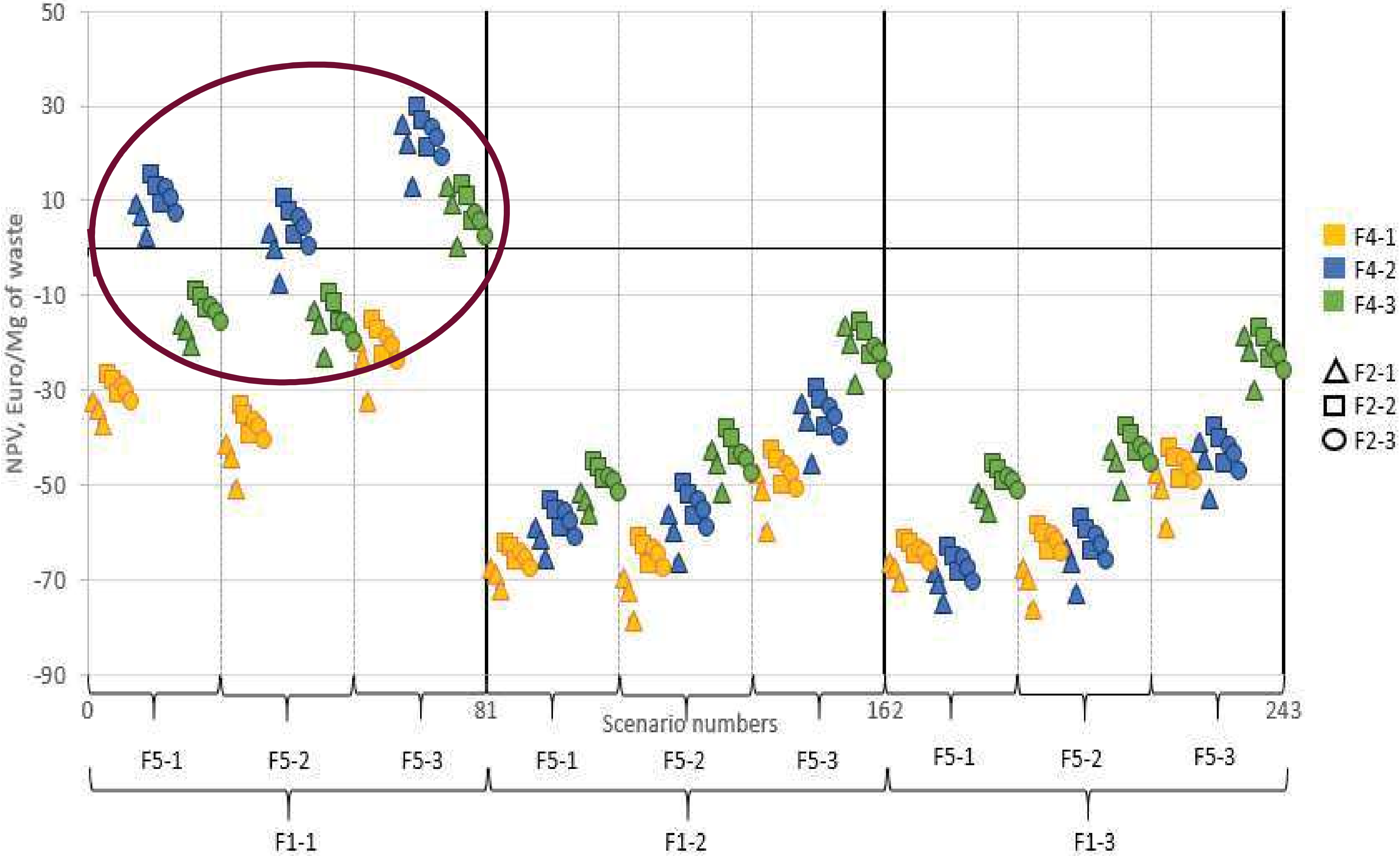
  5. – 8. F5 – Excavation & sorting technology 6%, F4 – Project drivers 5%, F8 – Value of land/void space 5%, F2 – Landfill composition 4%

  9. – 12. Variation in F11, F7, F0, and F10 alltogether accounts for less than 3% of total variation

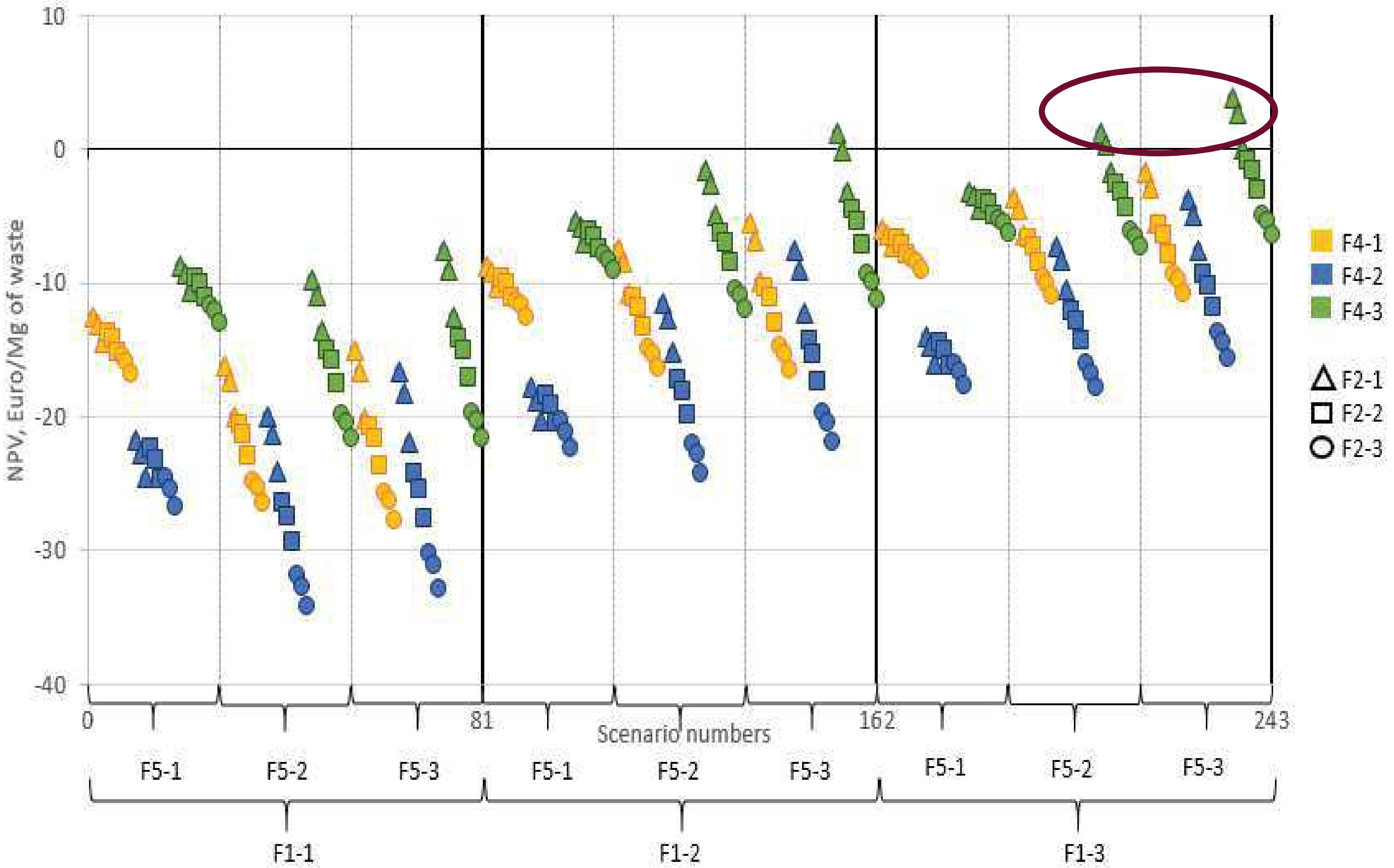
Graphical analysis of scenario results



Project economy in the high – high setting



Project economy in the low – low setting



Economy of LFM - Conclusions

- Landfill mining is a challenging business endeavour, which is highly dependent on the specific situation
  - NPV from -139 Euro (deficit) to +127 Euro (profit) per Mg of waste
    - Around 80% of the scenarios result in negative NPVs
    - Critical factors: 1. Costs for waste treatment, disposal and transport, 2. Reference scenario, 3. Costs for waste-to-energy, 4. Landfill settings.
  - Most important cost items
    - Treatment and disposal of excavated and processed materials
    - Excavation & sorting costs
  - Most important revenue items
    - Avoided costs of alternative landfill management
    - Material and land or void space recovery (if valorized) of similar importance
  - System-level conditions drive the major cost and revenue items
    - overarching boundary conditions to guide site selection and project development
    - Extreme of high income, high wmgt standards
      - minimize treatment costs more important than maximize material revenues
      - focus on landfills with low mass-to-area ratios → aftercare & land revenue
    - Extreme of low income, low wmgt standards
      - maximize material revenues rather than minimize (already low) treatment costs
      - focus on large landfills rich in valorisable materials

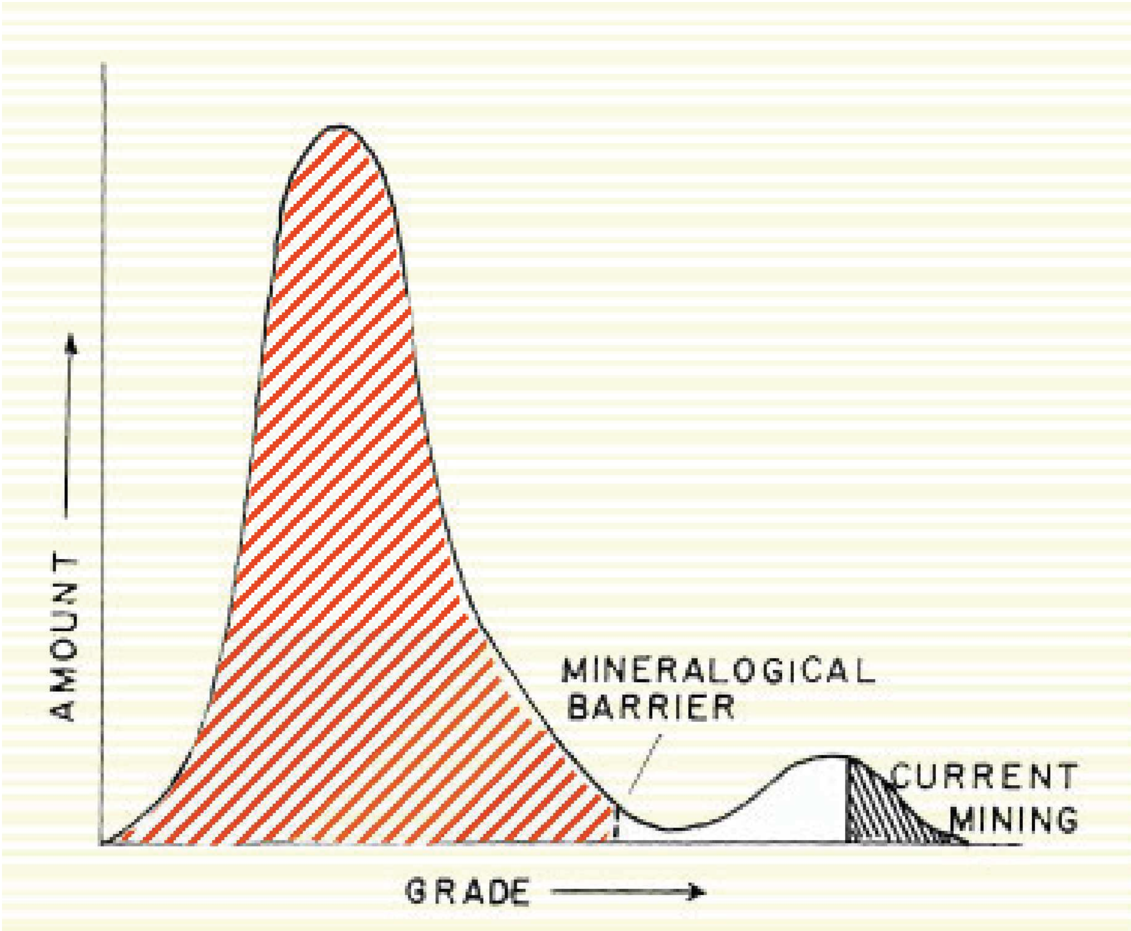
Critical factors for landfill mining… in general

- Landfill mining can offer a sustainable management option for a (small) part of Europe's landfills
  - If – in economic terms – multiple benefits can be obtained (materials **&** land **&** avoided management…)
  - If – from a circular economy perspective – key challenges of material quality and market acceptance can be overcome
  - If – from a societal perspective – diverse impacts on different societal scales and time horizons are better understood and internalized
  - If – from a policy perspective – landfill mining is seen as potential alternative to conventional practices and considered in regulatory frameworks

Outlook: what can we learn from primary production

Prospection:
Which landfills to mine?

Exploration & Production:
How to do it?
(in a long-term learning and institutional perspective)



Thank you for your attention!

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