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## Session 3

# **Generic framework for anthropogenic resource assessment**

# Content

1. Review on natural resource assessment
2. Review on anthropogenic resource assessment (ARA)
3. Need for a generic ARA
4. Proposal for a generic ARA
5. Discussion

# Literature review

## Natural resource assessments

(selected examples)

Oil & Gas	Minerals	Wind
USGS National Assessment of United States Oil and Gas Resources <sup>1, 2)</sup>	<ul style="list-style-type: none"> <li>• USGS Global Mineral Resource Assessments: Porphyry Copper Assessment of Europe <sup>3)</sup></li> <li>• BGS Industrial Mineral Resource Assessment <sup>4)</sup></li> </ul>	Review paper on wind resource assessment <sup>5)</sup>

1) USGS (1995). 1995 National Assessment of United States Oil and Gas Resources (U.S. Geological Survey Circular 1118). Washington.

2) Schmoker, J. and T. R. Klett (2005). U.S. Geological Survey Assessment Concepts for Conventional Petroleum Accumulations (U.S. Geological Survey Digital Data Series DDS-69-D). Denver.

3) Sutphin, D., et al. (2013). Porphyry Copper Assessment of Europe, Exclusive of the Fennoscandian Shield (Scientific Investigations Report 2010-5090-K). Reston.

4) British Geological Survey (2018). "Industrial minerals." Retrieved 16 September 2018, from <http://www.bgs.ac.uk/mineralsuk/mines/industrial.html>.

5) Murthy, K. S. R. and O. P. Rahi (2017). "A comprehensive review of wind resource assessment." Renewable and Sustainable Energy Reviews 72: 1320-1342.

# Conclusions

- “Assessment” is an overarching term for characterizing and/or evaluation and/or classifying resources in the prospection and exploration phase.
- Assessment methodologies (tools, models) are standardized and documented.
- Starting point for developing detailed exploration activities and recovery projects.

# Literature review

## Anthropogenic resource assessments

(selected examples)

N°	Target material	Material source	Region	Classification	Literature
1	Construction materials, metals	Subway network	Vienna	by analogy with McKelvey	Lederer, J., et al. (2016). "Prospecting and Exploring Anthropogenic Resource Deposits The Case Study of Vienna's Subway Network." Journal of Industrial Ecology 20(6): 1320-1333.
2	Phosphorus	Landfills, Soils	Austria	by analogy with McKelvey	Lederer, J., et al. (2014). "A framework for the evaluation of anthropogenic resources: the case study of phosphorus stocks in Austria." Journal of Cleaner Production 84(0): 368-381.
3	Plastics, textiles, paper, wood, glass, metals, etc.	Landfill	Local site in Belgium	by analogy with UNFC	Winterstetter, A., et al. (2015). "Framework for the evaluation of anthropogenic resources: A landfill mining case study – Resource or reserve?" Resources, Conservation and Recycling 96: 19-30.
4	Aluminium	Multiple sources	16 countries	Own classification, inspired by McKelvey	Maung, K. N., et al. (2017). "Assessment of secondary aluminum reserves of nations." Resources, Conservation and Recycling 126: 34-41.
5	Phosphorus Magnets fibre optic cable	fluorescent lamps electric cars infrastructure	Switzerland	Own classification, inspired by the UNFC	Mueller, S.R., Wager, P.A., Turner, D.A., Shaw, P.J. and Williams, I.D. (2017). A framework for evaluating the accessibility of raw materials from end-of-life products and the Earth's crust. Waste Manag. 68: p. 534-546.

# 1

Lederer, J., et al. (2016). "Prospecting and Exploring Anthropogenic Resource Deposits The Case Study of Vienna's Subway Network." *Journal of Industrial Ecology* 20(6): 1320-1333.

Abbreviated Table 1:

## Evaluation of natural and anthropogenic resource deposits

Mining stage	Aim	Natural deposit procedure	Anthropogenic deposit procedure
Prospection	Commodity or site-specific search for an ore	Retrieving secondary data and preparig primary data	Retrieving secondary data and preparig primary data
Exploration	Evaluating a prospect for its size, shape, grade, profit potential	Excavation, drilling, logging	Site visits and expert interviews
		Mathematical reserve estimates based on samples	Mathematical reserve estimates based on retrieved information
		Feasibility analysis (economic, legal, etc.)	Feasibility analysis (economic, legal, operational, etc.)

Derived from Hartman, H. L. and J. M. Mutmanský. 2002. *Introductory mining engineering*, 2nd ed. Hoboken, NJ, USA: Wiley.

## 2

Lederer, J., et al. (2014). "A framework for the evaluation of anthropogenic resources: the case study of phosphorus stocks in Austria." *Journal of Cleaner Production* 84(0): 368-381.

Fig. 4.

### Procedure for the evaluation of anthropogenic stock resources

Evaluation step	Method	Result
1. Prospection	Identification of stocks based on macro-level MFA	Relevant anthropogenic stocks identified and estimated
2. Exploration	Detailed stock characterization based on micro-level studies	Grade, size of stock, uncertainties
3. Evaluation	Selection of technologies and economic analysis of costs and revenues	Costs/revenues ratio
4. Classification	McKelvey cross classification	Reserves, resources, and other occurrences of anthropogenic stocks

# 3

Winterstetter, A., et al. (2015). "Framework for the evaluation of anthropogenic resources: A landfill mining case study – Resource or reserve?" Resources, Conservation and Recycling 96: 19-30.

Abbreviated table 1:

## Operative procedure for evaluating a landfill-mining project.

Mining stage	Aim	Localization in UNFC	Methods for decision making
Prospection	First estimates on resource potential: selection of a project	-	Macro scale MFA; analysis & evaluation of landfill statistics & literature data on waste composition
Exploration	Gain knowledge on size & composition of a specific deposit: landfill's total resource potential	G-axis	....
	Field project status & technical feasibility of recovery & valorization regarding quantities & quality: amount of extractable & potentially usable resources	F-axis	....
Evaluation	Socioeconomic viability including direct financial effects & non-monetary modifying factors	E-axis	.....
Classification	Combination of all criteria & classification under UNFC-2009	-	-



# 4

Maung, K. N., et al. (2017). "Assessment of secondary aluminum reserves of nations." Resources, Conservation and Recycling 126: 34-41.

Abbreviated Table 1

## Framework for classification of secondary resources

(modified from Hashimoto et al. (jointly submitted paper under review).

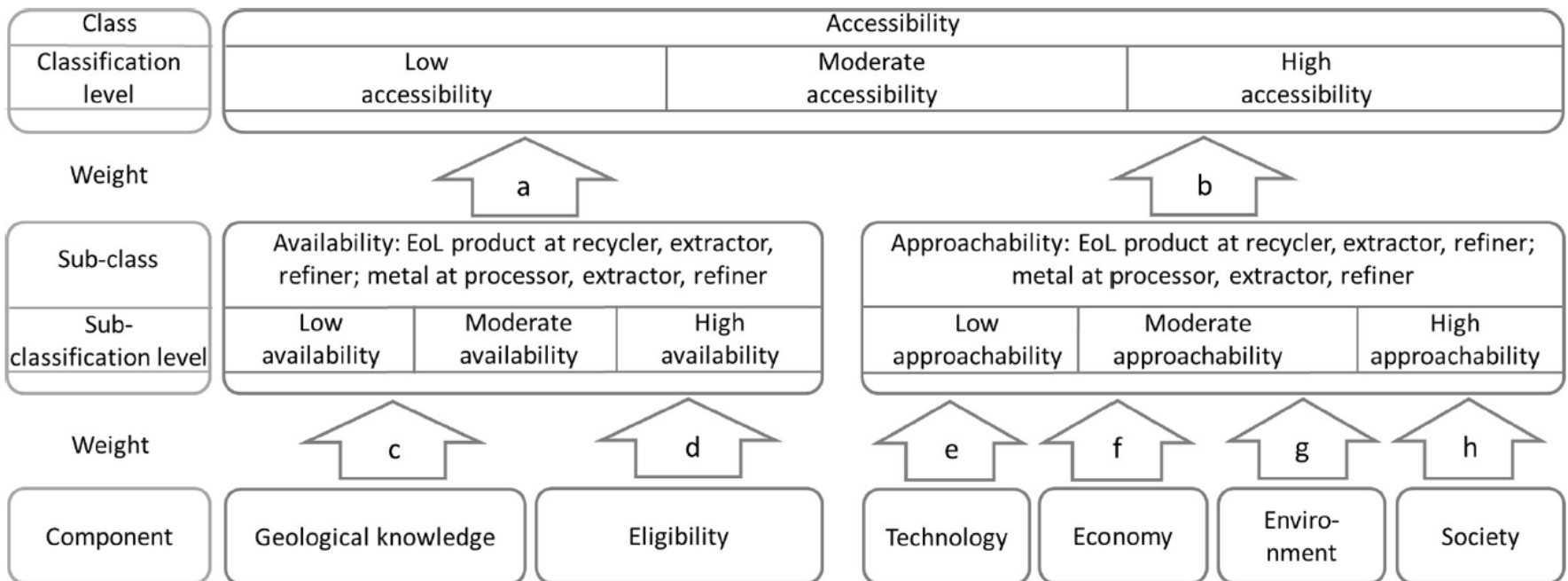
	Final products in/after use	
	Emerging in a year	Not emerging in a year
Economic	Secondary reserves in a year	Secondary reserves in future
Marginally economic	Marginal secondary reserves in a year	Marginal secondary reserves in future
Sub-economic	Sub-economic secondary resources in a year	Sub-economic secondary resources in future
Other	Unrecoverable materials (other)	Unrecoverable materials (other)

# 5

Mueller, S.R., Wager, P.A., Turner, D.A., Shaw, P.J. and Williams, I.D. (2017). *A framework for evaluating the accessibility of raw materials from end-of-life products and the Earth's crust*. Waste Manag. **68**: p. 534-546.

Fig. 5

## Evaluation framework for raw material accessibility....



# Conlusions

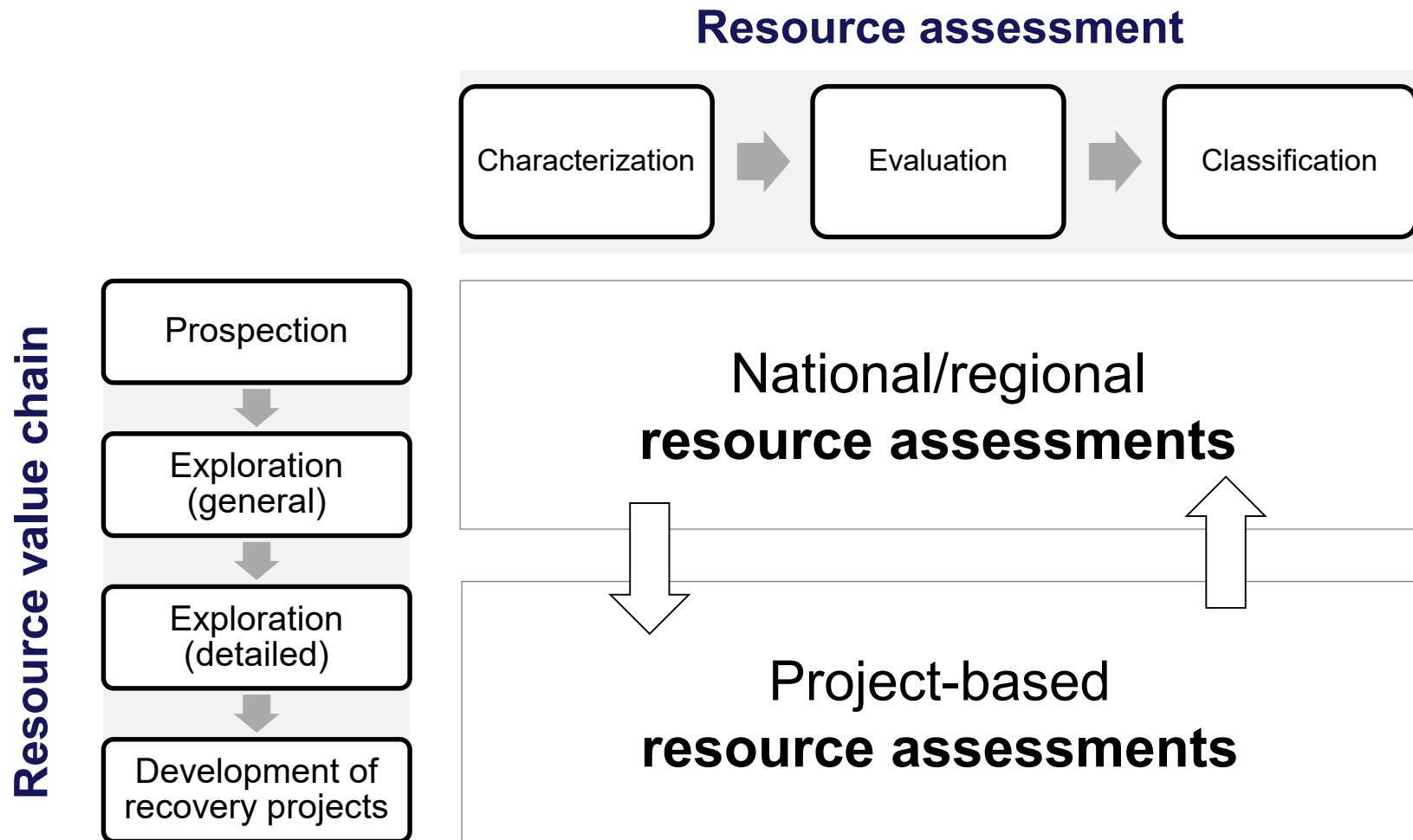
## ARA

- Selection and definition of „mining stages“ varies
- Assessment frameworks always include a specific resource classification
- A generic framework for anthropogenic resource assessment is neither available nor standardized

# The need for a generic ARA

- AR classification is rather new and needs to be demonstrated in context of a AR assessment
- A generic ARA helps to
  - communicate the scope of case studies
  - demonstrate the benefits/challenges of assessment tools and their linkages
  - compare different case studies and to learn from each other
  - demonstrate the linkage between national and project-based approaches

# Proposal for a generic ARA



# Proposal for a generic ARA

		Characterization	Evaluation	Classification
<div>Selec. &amp; def. exploration projects</div> <div>Selec. &amp; def. recovery projects</div>	Prospection	Search & investigation of unknown material sources	Defining criteria for the selection of sources	Categorizing the quantities with UNFC (E ? F3 or F4 G1-3).
	Exploration (general)	Characterizing potential material sources	Assessing (non-) recoverable material quantities from a technological, environmental, social, economic, legal and political perspective.	
	Exploration (detailed)			
	Development of recovery projects	Characterizing known material sources		Categorizing the quantities with UNFC (E? F2 or F1 G?).

# Questions

- Is there a need for generic framework for ARA?
- Is there a need for changing the proposed framework?
- What should be the outcome of the phases in the “value chain” and the “assessment”?
- How can the phases be defined/described?