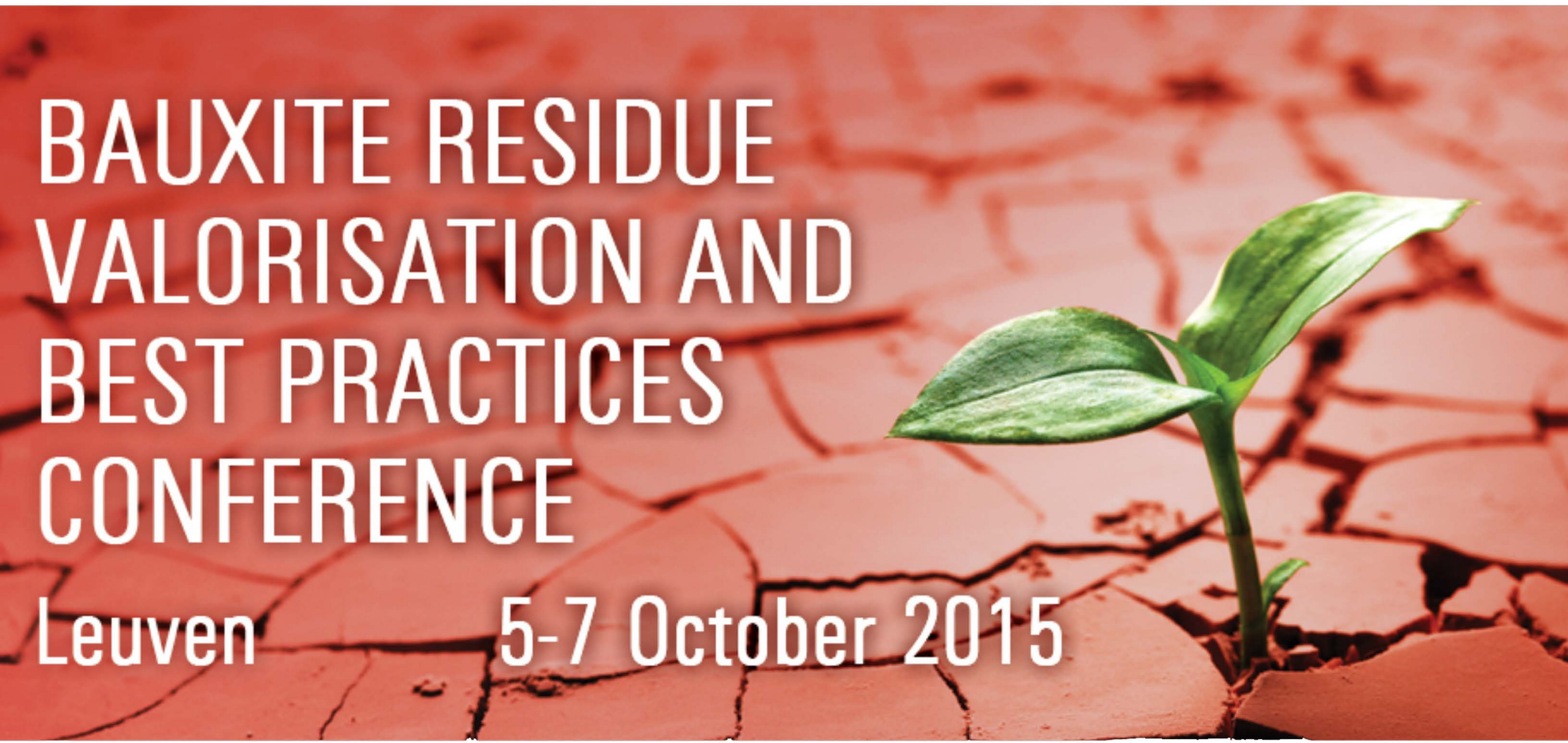
BAUXITE RESIDUE VALORISATION AND BEST PRACTICES CONFERENCE



Leuven 5-7 October 2015

Incorporating the radiological effects and environmental impact assessment of NORM into the life cycle environmental optimisation of BR valorisation

James Joyce,
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Anna Björklund

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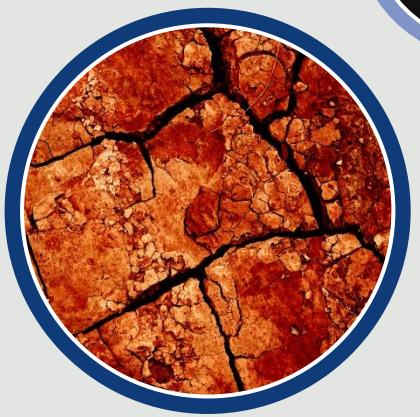
OUTLINE

- What is Life Cycle Assessment (LCA)?
- What do we mean by NORM?
- Relation to Bauxite Residue Valorisation
- Integrating NORM into LCA
- Results to date



LCA

ETN-MSCA
REDMUD

LIFE CYCLE ASSESSMENT

Standardised, internationally recognised method for assessing the environmental impact of products and processes on a holistic basis

ISO 14040/44

"[The] compilation and evaluation of the inputs, outputs and potential environmental impacts of a product system throughout its life cycle"

LIFE CYCLE ASSESSMENT

Everything has a life story

Including everything in this room


Raw material extraction


Production

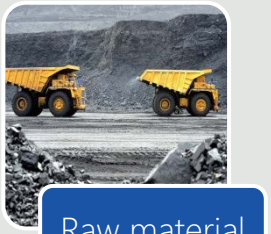

Distribution


Use


End of life

LIFE CYCLE ASSESSMENT

- LCA assesses the environmental impact that occurs across all of these 'life cycle stages'
- Gives a holistic picture of the environmental impact caused by the product modelled across multiple 'impact categories'
- Allows you to identify **hotspots** (and 'cold-spots')



Raw material extraction

Production

Distribution

Use

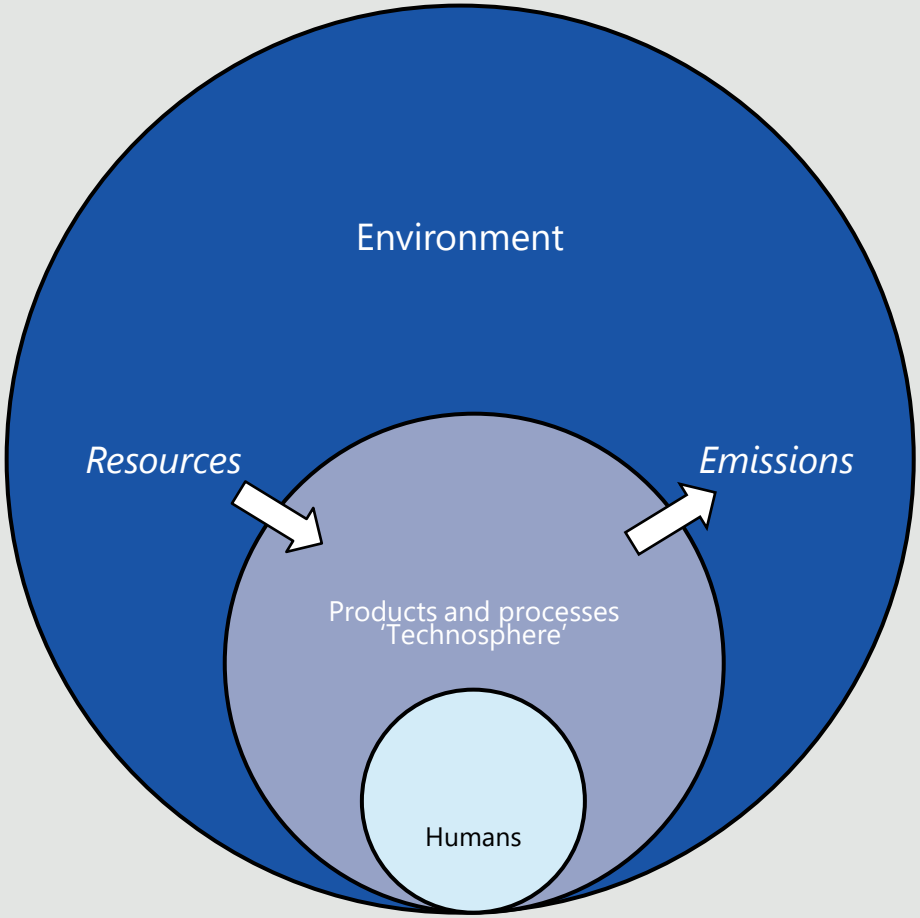
End of life

High contribution to overall impact (Hotspot)				
Resource depletion			GHG emissions	Toxicity impacts

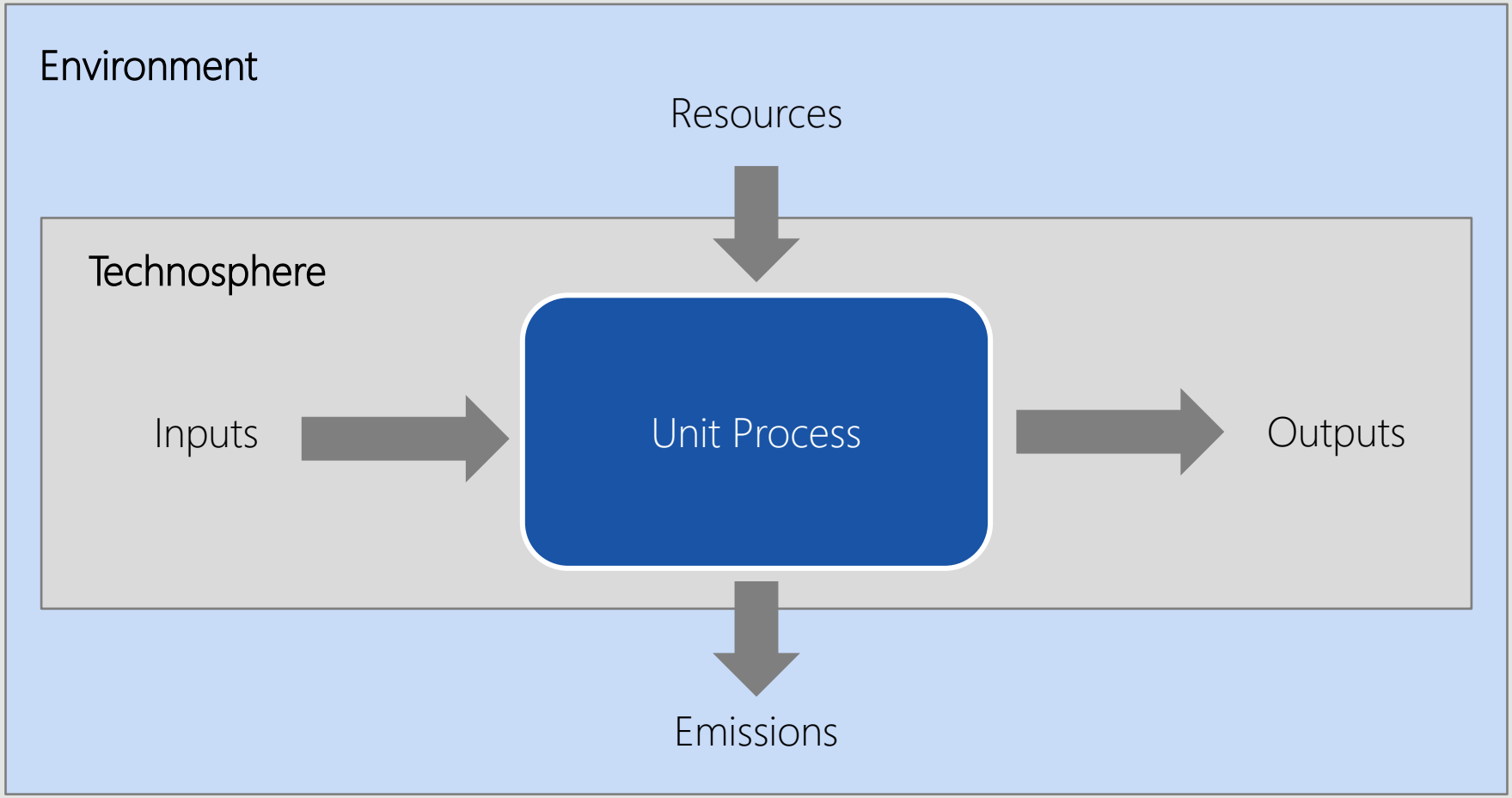
Low contribution to overall impact ('Cold spot')				
		GHG emissions	Resource depletion	

LIFE CYCLE ASSESSMENT

- Humans operate within our constructed system of products and processes
- These products and processes interact (exchange substances and energy) with the environment
- LCA models and quantifies these exchanges



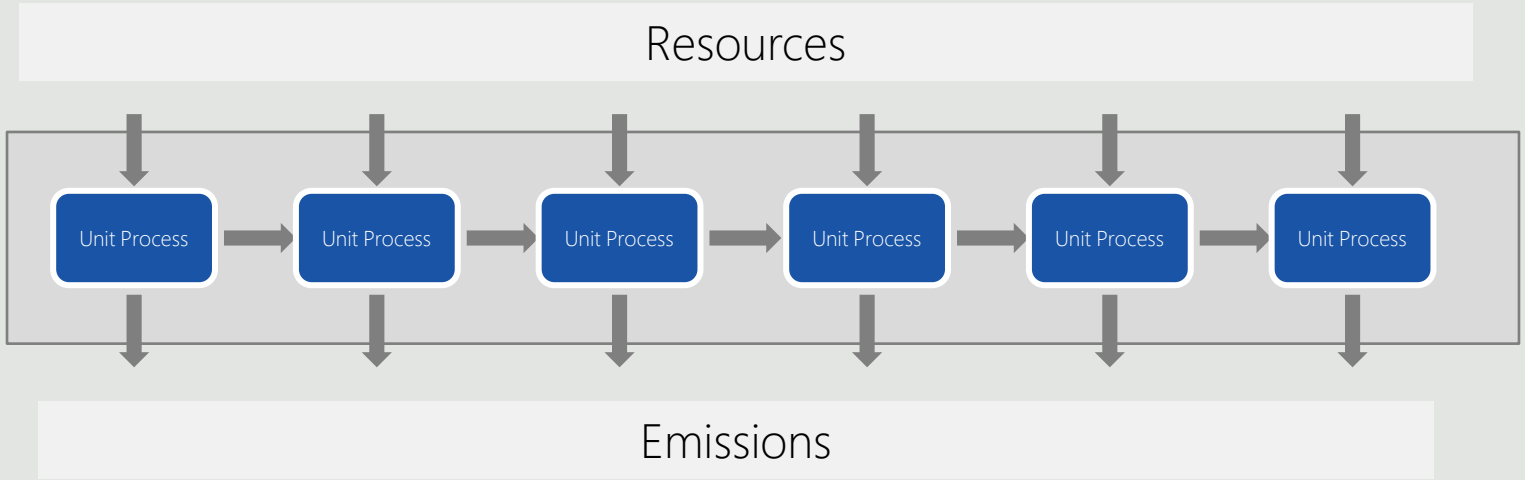
LIFE CYCLE ASSESSMENT



LIFE CYCLE ASSESSMENT

- A **life cycle model** is a connected system of unit processes

- The output of the life cycle model is a complete inventory of 'exchanges' with the environment, called a **life cycle inventory or LCI**



LIFE CYCLE ASSESSMENT

- Resources and emissions in the LCI are 'classified' according to the impact categories of interest

Substance	Amount (kg)
…	…
Carbon Dioxide (to air)	1
Methane – fossil (to air)	1
N_2O (to air)	1
Iron (from ground)	1
Molybdenum (from ground)	1
…	…

Specific sets of Characterisation factors

Global Warming (kg CO_2-eq)	Metal Depletion (kg Fe-eq)
…	…
1	X
25	X
298	X
X	1
X	208
…	…
324	209

Total

Example Impact Categories

Climate Change
Eutrophication
Acidification
Particulate Matter Formation
Ozone Depletion
Human Toxicity
Ecotoxicity
Ionising Radiation
Fossil Depletion
Metal depletion

WHAT IS NORM?

Naturally **O**ccurring **R**adioactive **M**aterial

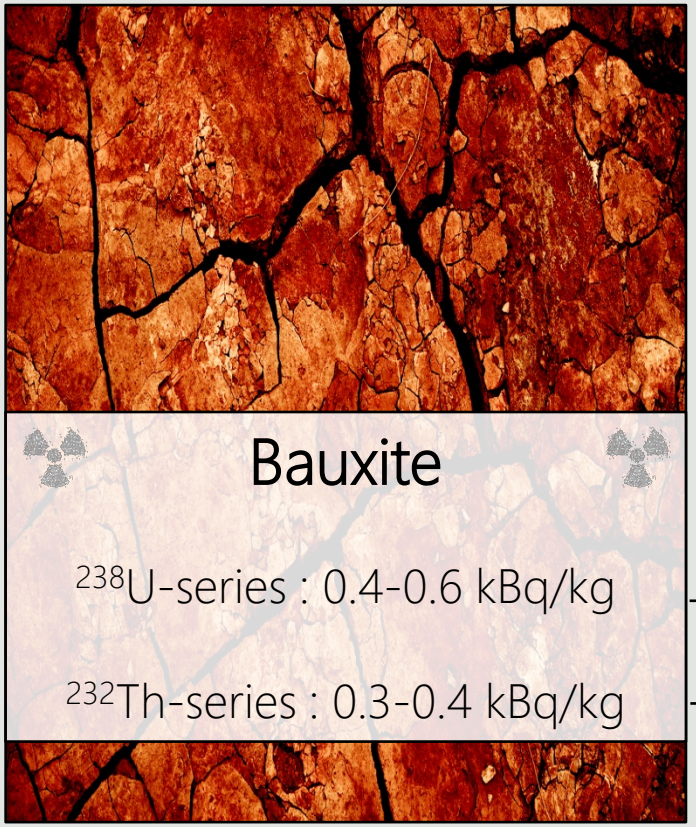
More specifically:

All naturally occurring radioactive materials where human activities have increased the potential for exposure compared with the unaltered situation

Where concentration of these elements is increased through human actions, it is classed as Technologically Enhanced (Naturally Occurring) Radioactive Material

TENORM or TERM

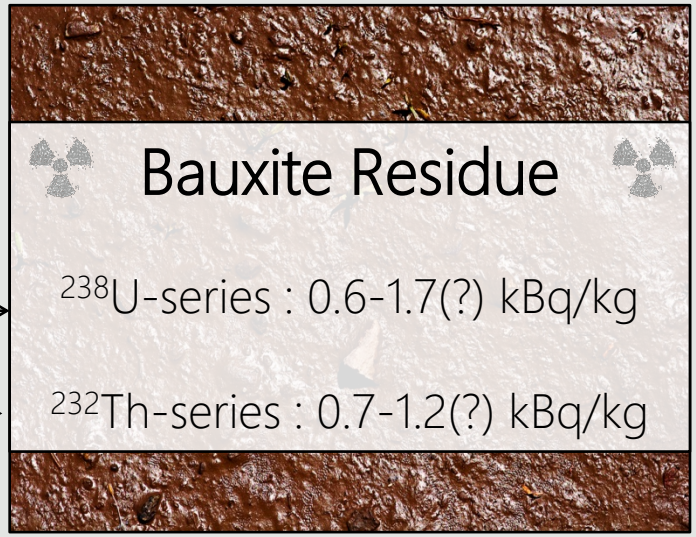
NORM IN BAUXITE RESIDUE VALORISATION



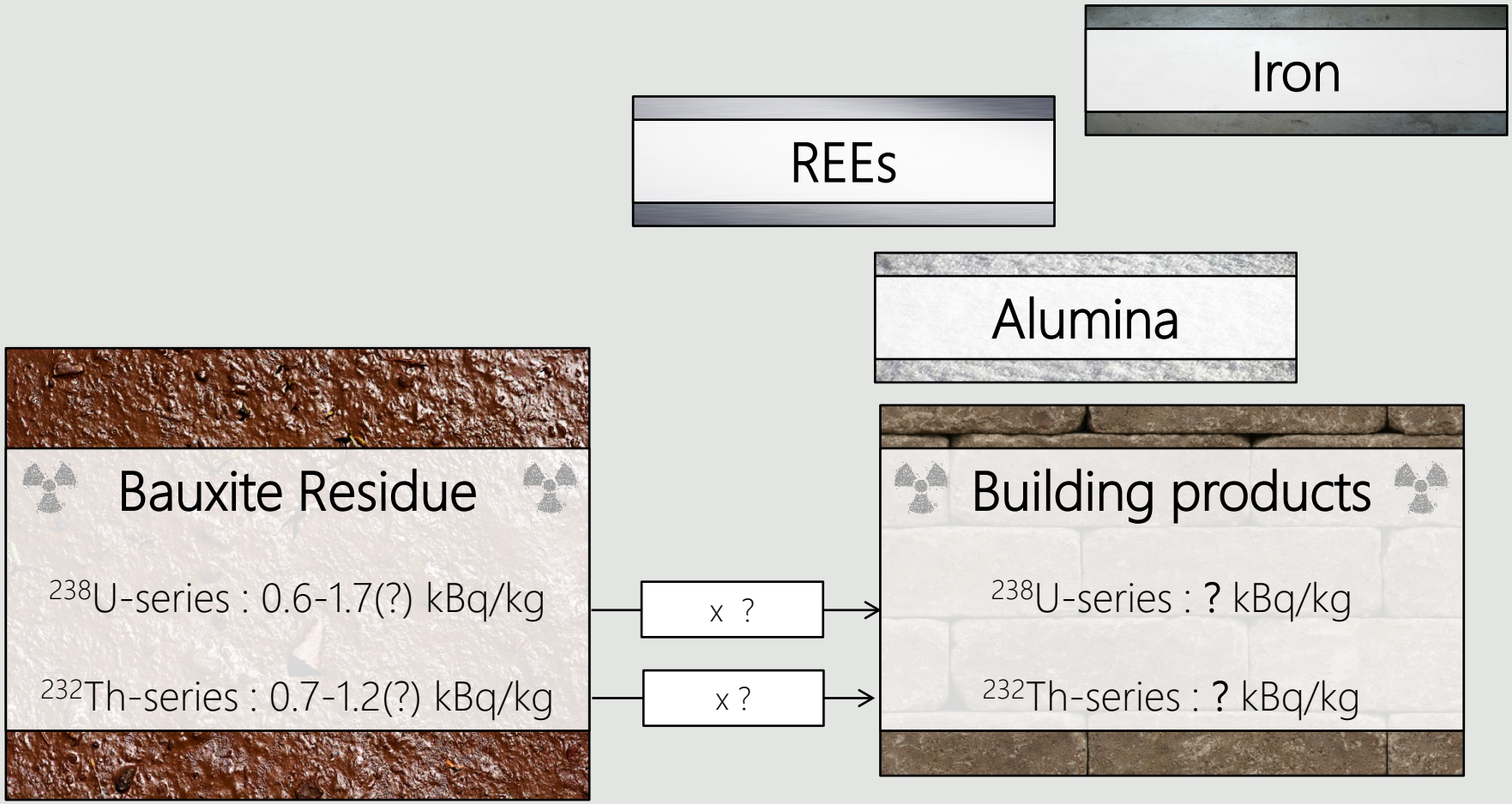
x 1.6 - 2.9

x 2.4 – 3.0

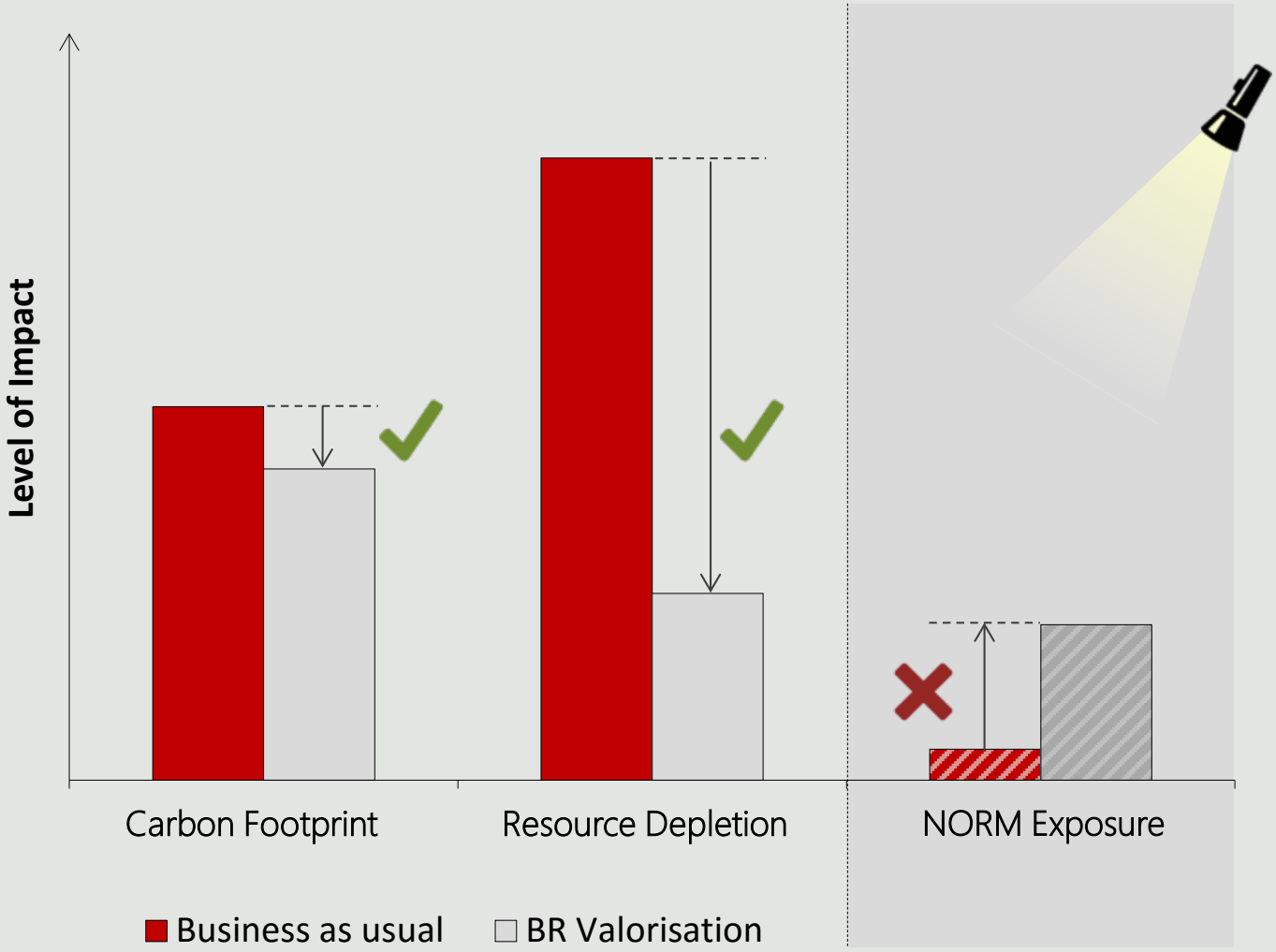
Alumina



NORM IN BAUXITE RESIDUE VALORISATION

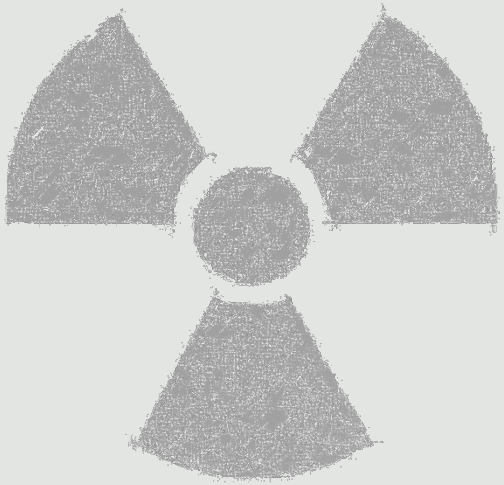


BURDEN SHIFTING



‘STATE OF THE ART’ FOR RADIATION IN LCA

- Two impact categories exist
  - Ionising Radiation - Human Health
  - Ionising Radiation – Environmental
- Focus on nuclear fuel cycle
- Neither include all NORM nuclides
- Exposure through products not considered
- A new characterisation method is required



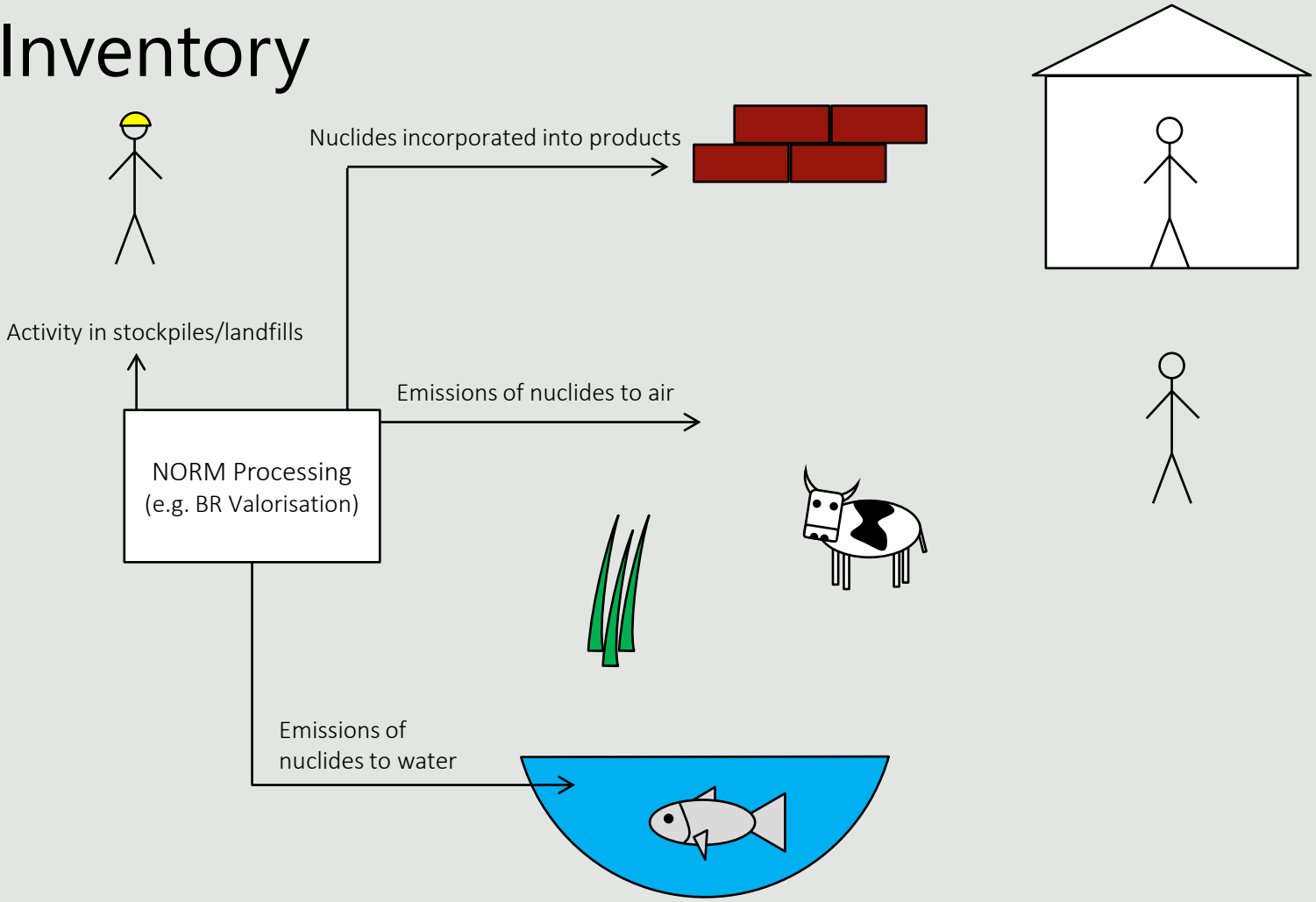
CHARACTERISATION METHOD

1. Inventory
2. Fate
3. Exposure
4. Damage

NORM Processing
(e.g. BR Valorisation)

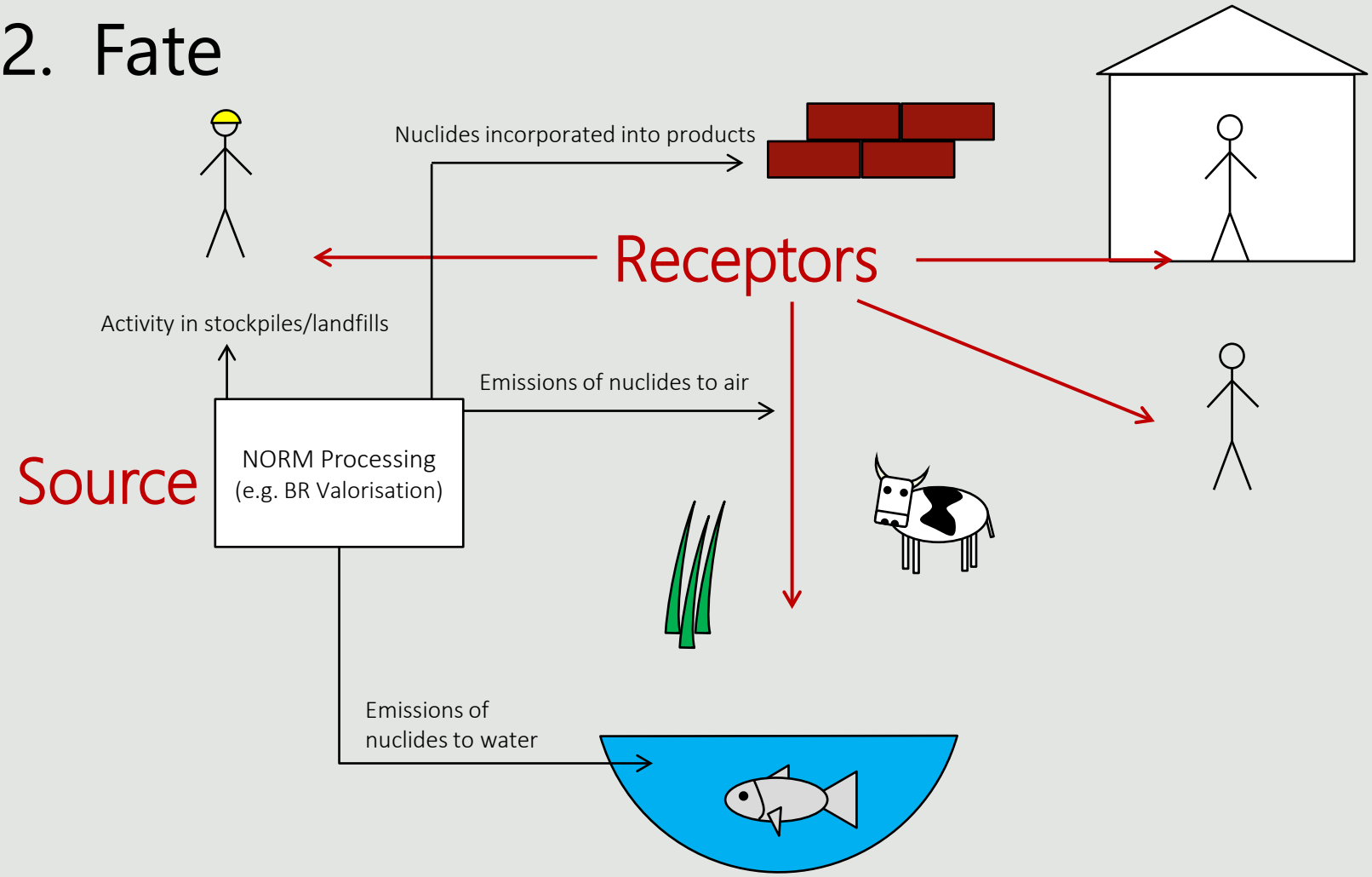
CHARACTERISATION METHOD

1. Inventory



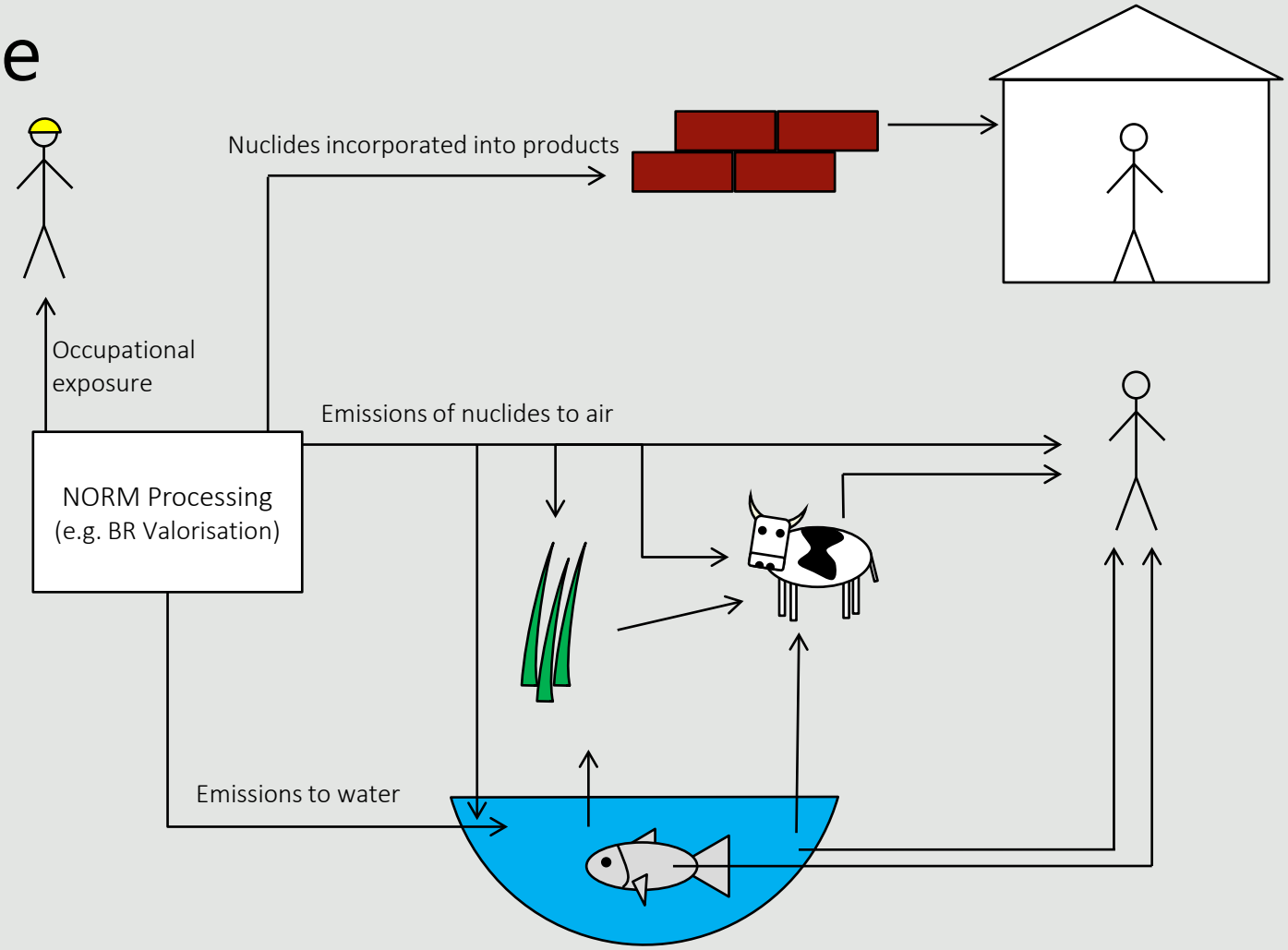
CHARACTERISATION METHOD

2. Fate



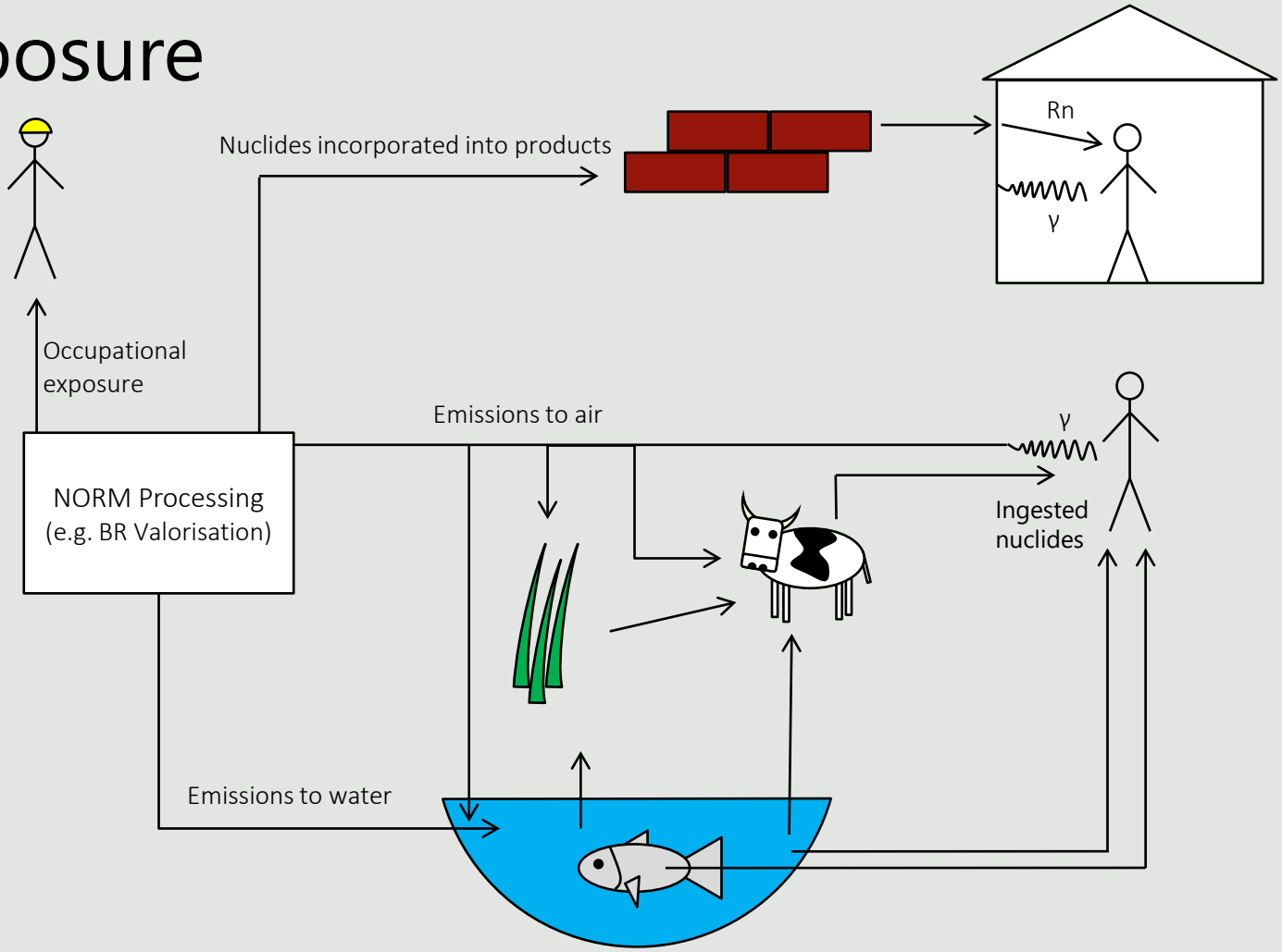
CHARACTERISATION METHOD

2. Fate



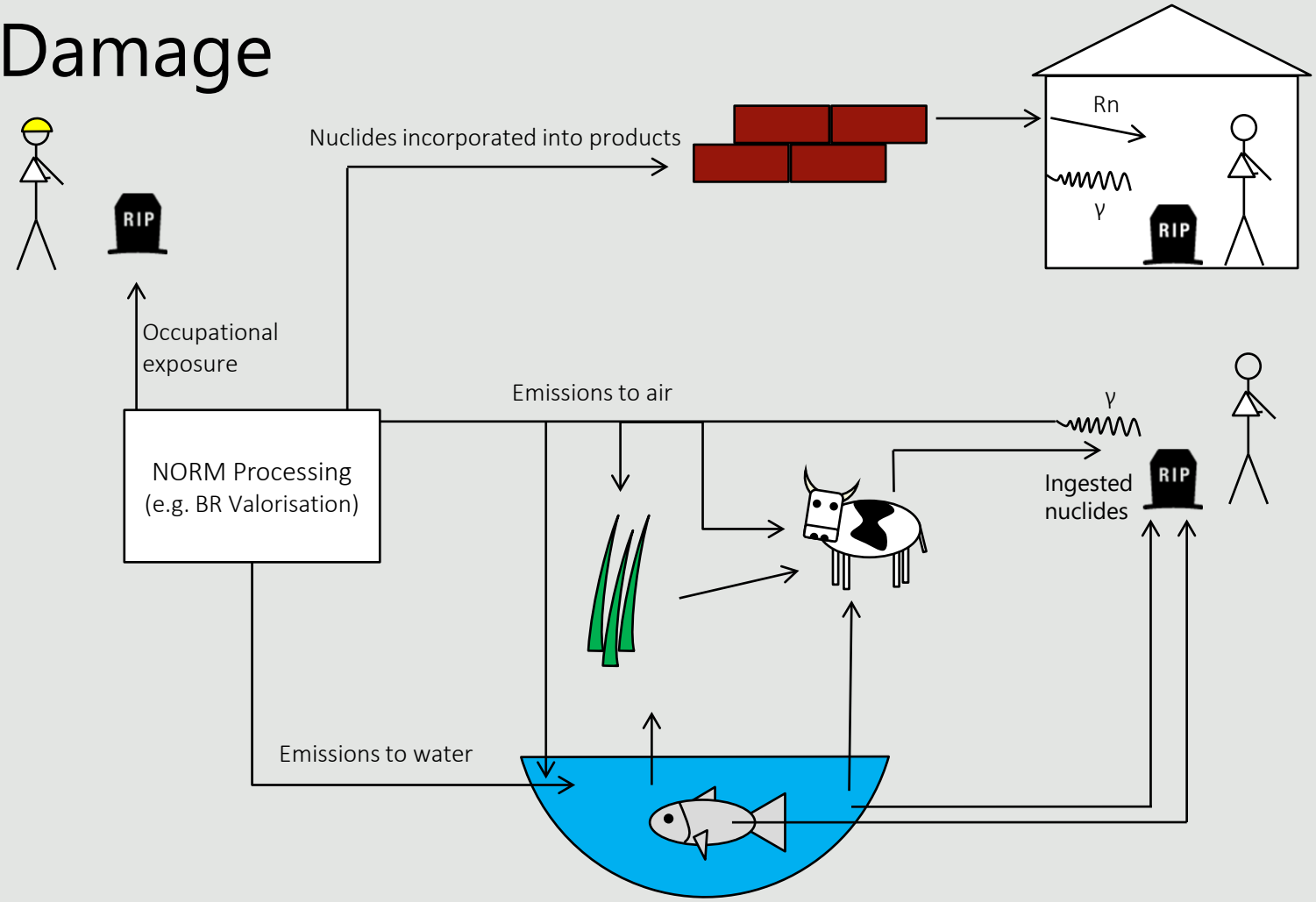
CHARACTERISATION METHOD

3. Exposure



CHARACTERISATION METHOD

4. Damage

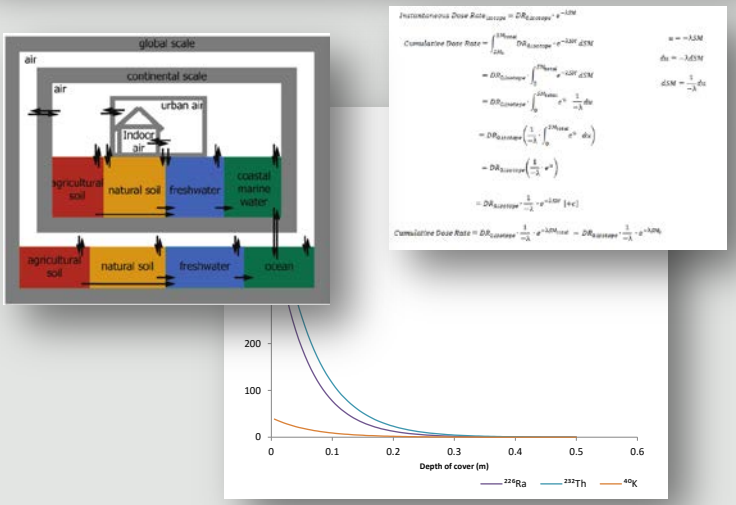


CHARACTERISATION METHOD

- Models for various steps and stages in the framework exist
- Next steps
  - Make necessary adjustments
  - Connect models into coherent whole
  - Validate against BR valorisation techniques

LCA step	Release to the environment				Occupational exposure				Building materials					
	Human impact		Biota impact		Human impact				Human impact					
					Storage		Handling		Gamma dose		Radon dose			
Inventory analysis	Mass balance	*			Measure-ments	*	Impact considered negligible	x	Measurements	*				
Fate analysis	USEtox (Rosenbaum et al. 2008)	*			Markkanen (1995)	*			Considered to be immobile	x	UNSCEAR(2000)	*		
Exposure analysis	UNSCEAR (2000)	*	ERICA (Brown et al. 2008)	*	UNSCEAR (2000)	*			Meijer et al. (2005)	*	UNSCEAR (2000)	*		
									UNSCEAR (2000) for effective dose	*				
Damage analysis	Disability adjusted life years (DALY) (Frischknecht and Braunschweig 2000)	*	Screening level ecological risk assessment (Brown et al. 2008)	*	Disability adjusted life years (DALY) (Frischknecht and Braunschweig 2000)	*			Disability adjusted life years (DALY) (Frischknecht and Braunschweig 2000)					

* Model requires little or no revision **Model requires minimal revision ***Model requires extensive additions/revisions X Not relevant



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Alan Tkaczyk (UT)
Andrei Goronovski (UT)

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