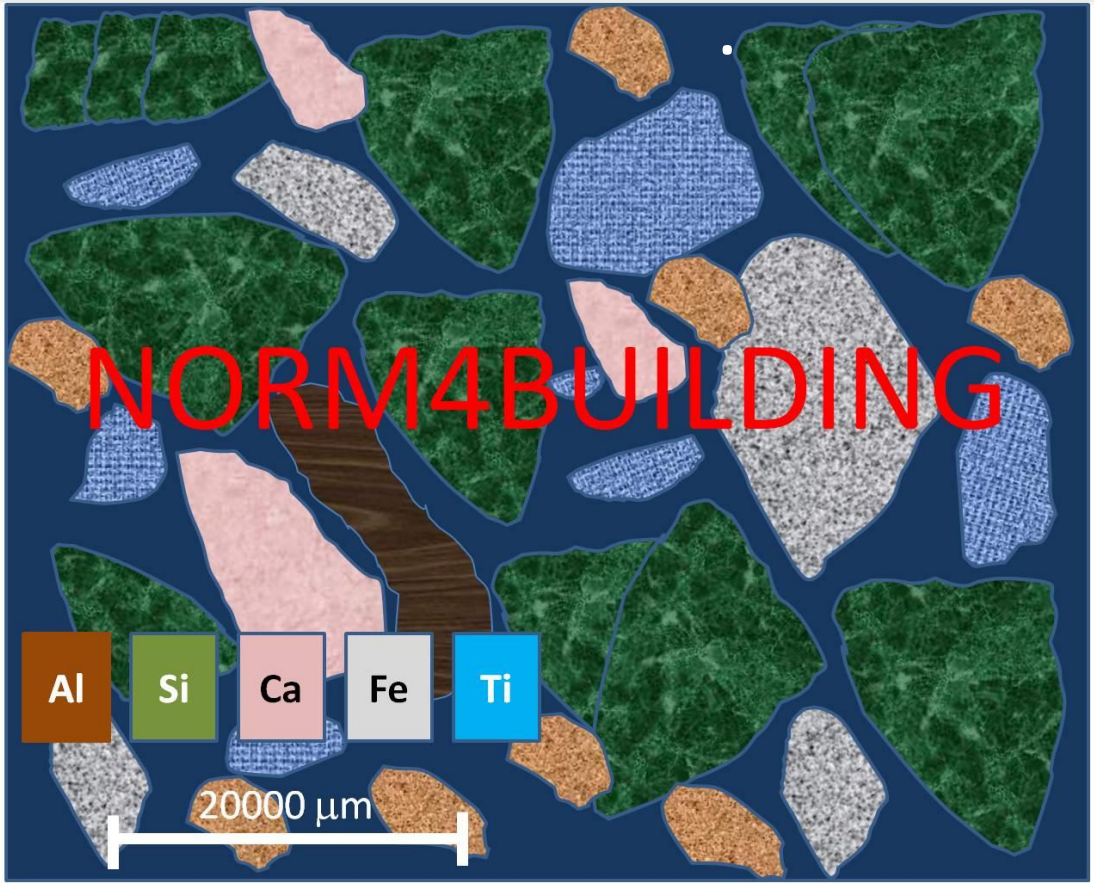
# Towards a holistic approach for risk assessment when reusing slag with enhanced NORM content in building materials




Leuven 17/04/2015

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NuTeC, UHasselt, Belgium

Transport and Urban Development (TUD)

# NuTeC

**Nu**clear **Te**chnological **C**enter (**NuTeC**, www.nutec.be)
Center of Environmental Studies (**CMK**, www.uhasselt.be/cmk)

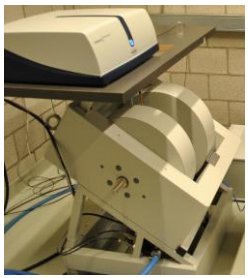
Industrial Sciences: **"Nuclear and environmental Engineering"**

- Environmental Technology-Radiochemistry
- Medical Nuclear Technology

Application and development of nuclear measurement methods

Environmental and energy related research (pyrolysis)

EMR dosimetry



# *Reusing slag with enhanced NORM content in building materials*

1. **Taking into account NORM in the risk assessment?**

2. Scientific approach NORM4Building network

3. Collaboration opportunities

# NORM

**Ore:** **'N**aturally **O**ccurring **R**adioactive **M**aterials'

**Processing**

Residues with enhanced concentrations of NORM







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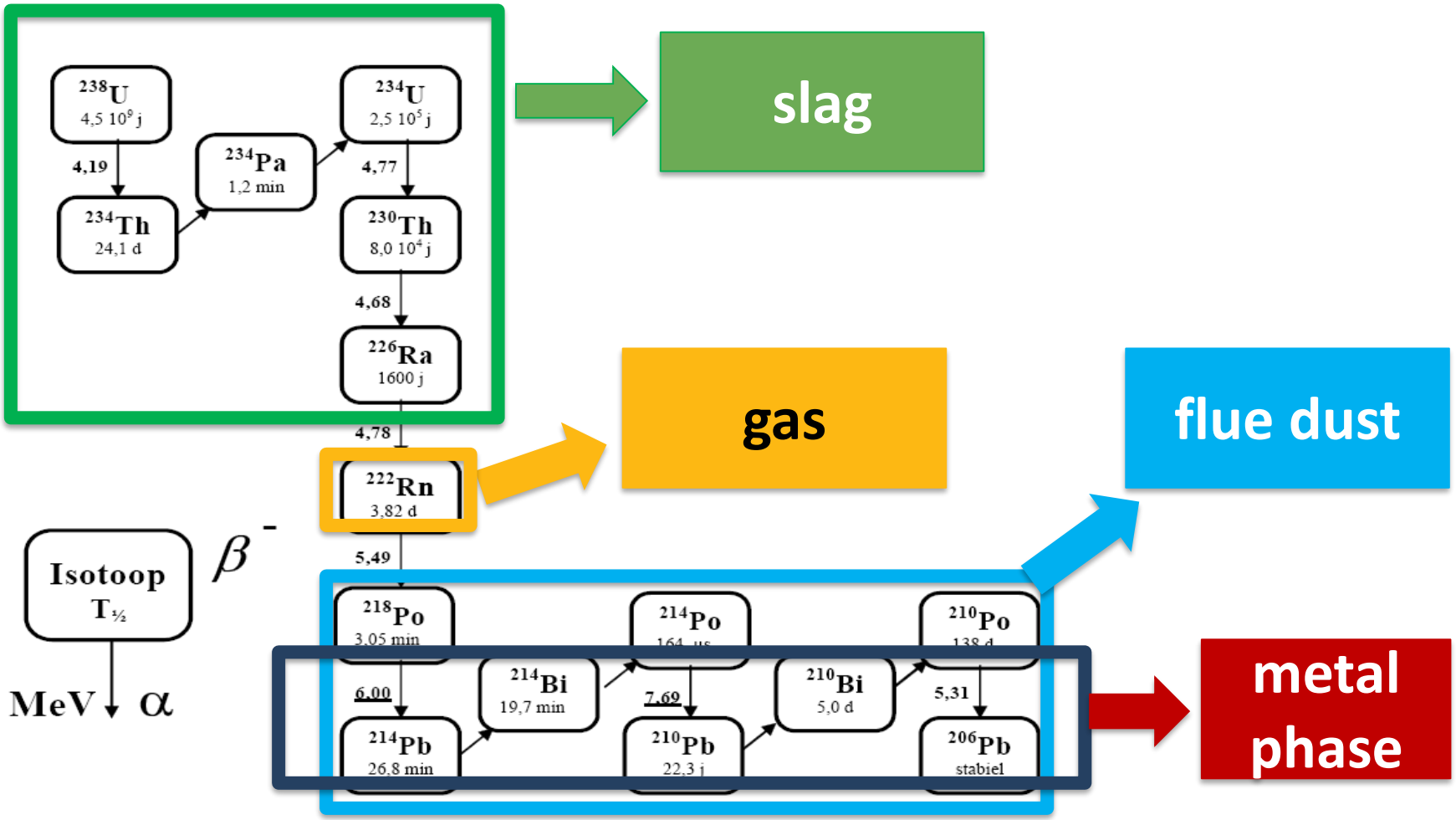
# Metal processing: how radionuclides (U-238 decay chain) can behave during smelting?




(similar for decay chain of Th-232)

# NORM processing industries (EU-BSS ANNEX VI)

- extraction of rare earths from monazite;
- production of thorium compounds and manufacture of thorium-containing products;
- processing of niobium/tantalum ore;
- oil and gas production;
- geothermal energy production;
- $TiO_2$ pigment production;
- thermal phosphorus production;
- zircon and zirconium industry;
- production of phosphate fertilisers;
- cement production, maintenance of clinker ovens;
- coal-fired power plants, maintenance of boilers;
- phosphoric acid production;
- primary iron production;
- tin/lead/copper smelting;
- ground water filtration facilities;
- mining of ores other than uranium ore.

Including relevant secondary processes
Member States can add other relevant activities

# Reuse in building materials

| Residues from NORM processing industry (with interesting properties for reuse in building materials) | Codification EU-Waste Catalogue? | Estimated production (Milion Tons/year) |
|---|---|---|
| coal fly-ash | 001 02 or 10 01 16 | 44 (2003, EU 15) [1] |
| slag and bottom ash from a coal-fired power plant | 10 01 01 or 10 01 14 | 8 (2003, EU 15) [1] |
| phosphorous slag from thermal phosphorus production | 06 09 02 | - |
| phosphogypsum from phosphoric acid production, | - | 180 (2003, World) [2] |
| red-mud, (bauxite residue), from alumina production | 01 03 07 | 120 (2003, World) [3] |
| unprocessed slag from primary iron production | 10 02 02 | 260-310 (2011, World) [4] |
| steel or stainless steel, lead slags | 10 04 01 | 130-210 (2011, World) [4] |
| copper slags, from primary and secondary production. | 10 06 01 | 24,6 (2009, World) [5] |
| tin slags from primary and secondary production | - | - |
| specific residues originating from pyro- and hydro-metallurgies producing platinum group metals or rare earth elements | - | - |


[1] Ecoba - SPECIAL PRINT CPI 04/06
[2] A.B. Parreira, A.R.K. Kobayashi Jr., O.B. Silvestre, J. Environ. Eng. 129 (2003) 956–960
[3] www.redmud.org/Disposal.html
[4] U.S. Geological Survey, Mineral Commodity Summaries, January 2012
[5] S.H. Chew, S.K. Bharati, Proc. Of Int. Symp. On Geoenvironmental Eng., ISGE2009, 705, 2009

# New Euratom-BSS in addition to CPR

Residues of NORM processing industry to be recycled in building materials?

**BSS Art. 75.2 + Indicative list in Annex XI + CPR**

Yes

$$ACI = \frac{C_{Ra226}}{300}\frac{Bq}{kg} + \frac{C_{Th232}}{200}\frac{Bq}{kg} + \frac{C_{K40}}{3000}\frac{Bq}{kg}$$

C in Bq/kg

**Index ≤ 1?**

Results may be requested by the regulatory authority

**TS 351014 + CPR art. 18 + BSS Annex VII & VIII**

No

**BSS Art. 75**

**Specific national requirements or restrictions taking into account:**

Density; thickness of the material; factors relating to materials and intended use of it (bulk or superficial)

***(Gamma)*** Dose **estimate < 1 mSv/year**

**"Declaration of performance"**

**CE marking + classification**

to be made available to the consumers

**CPR Art. 4, 8.2, 8.3, 11, 24**

**+ EU harmonized standards CEN-TG 32**

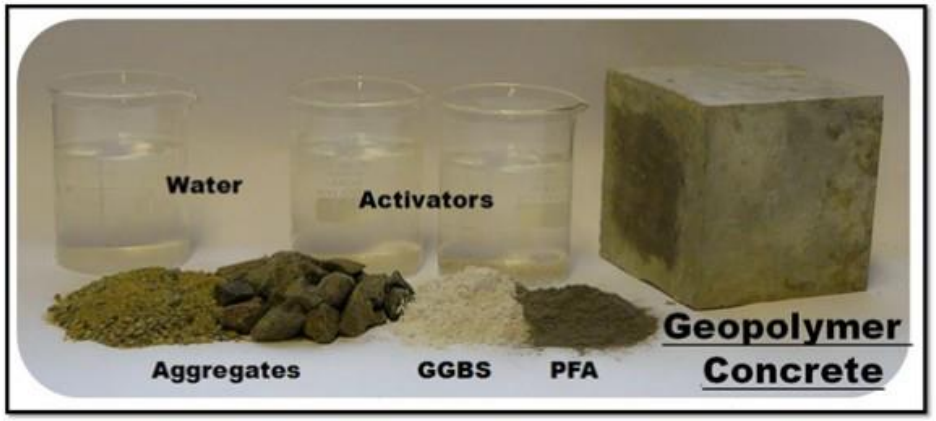
Yes

No regulatory control

**BSS Art. 26 & 30 and Annex VII Table A part 2**

# NORM in building materials (New European Directives, **Annex XI**)

- Materials including by-products or residues from NORM industries such as
  - fly ash,
  - phosphogypsum,
  - phosphorous slag
  - tin slag
  - copper slag
  - red mud (residue from aluminium production)
  - residues from steel production



# Using NORM for building materials?

**Fly ash**

**Phosphogypsum**

**Metal slag**

**Red mud**

**Ceramics**

**Concrete**

**Cement**

- Suitable chemical and physical properties?
  - (Pre)treatment of residues?
- Gamma exposure towards occupants?
- Indoor air quality?
  - Radiological and chemical noxes?
- End-of-life considerations?
  - Leachability?

A need to check under what conditions materials can be used and where!

Focus on reuse of residues in

Ceramic

Cement Geopolymers

Concrete

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# *Reusing slag with enhanced NORM content in building materials*

1. Taking into account NORM in the risk assessment?

2. **Scientific approach NORM4Building network**

3. Collaboration opportunities

# Main objective 'NORM4BUILDING'

- Exchange of multidisciplinary knowledge and experiences (radiological, technical, economical, legislative, ecological, …)

Stimulate the
**reuse of NORM residues in new tailor-made sustainable building materials**
while
**considering exposure to external gamma radiation and the resulting indoor air quality.**

# COST - network

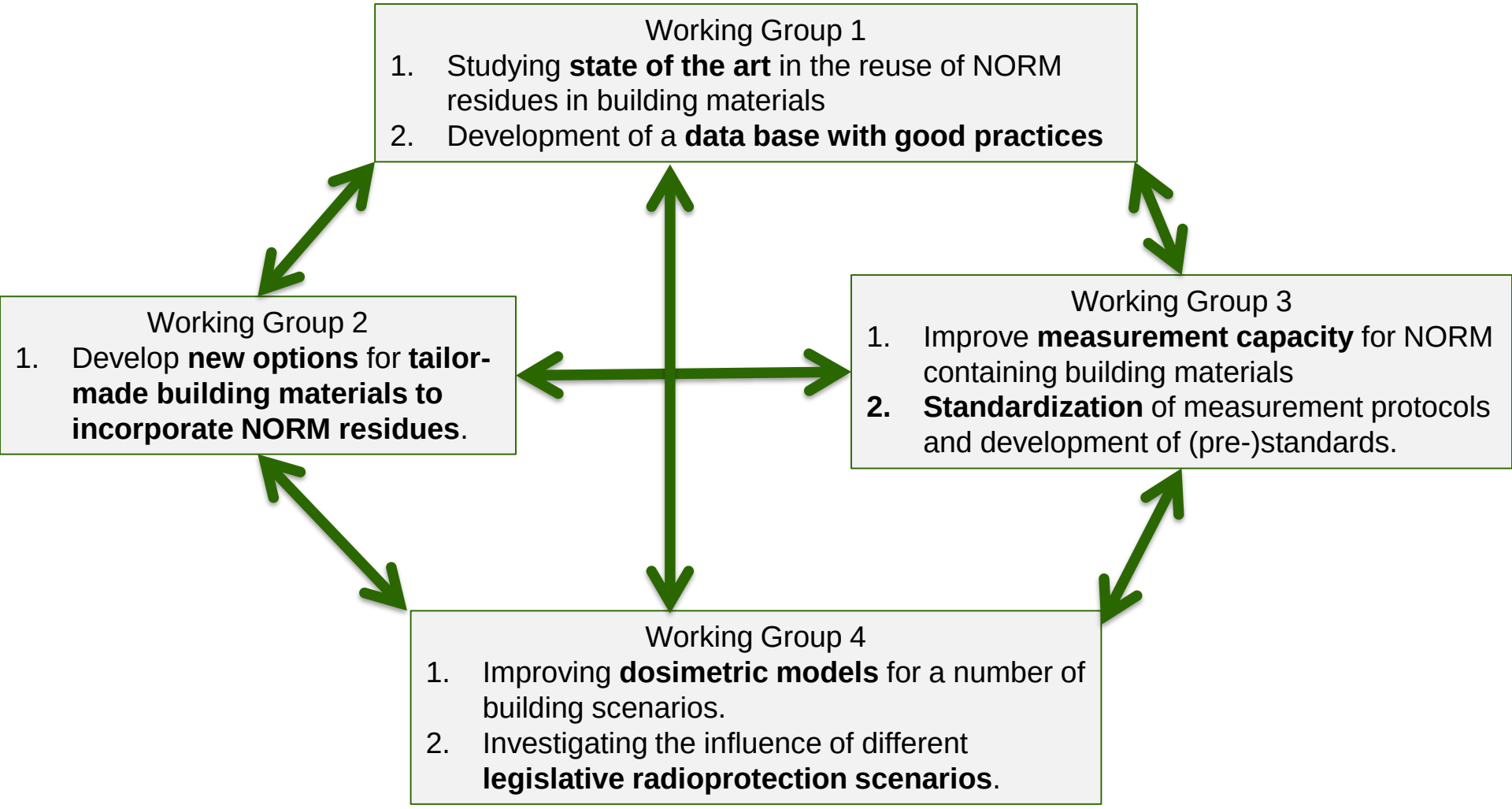
(Research and Technological development Framework Program)

- ORGANIZATION OF MEETINGS:
  - **12-13/02/2014 Israel, Dead Sea Hotel**
    - Linked to **INS conference**
  - **16-17/06/2014 Czech Republic, Prague**
    - Linked to **EU-NORM 2 symposium**
  - **17-18/09/2014 UK, Sheffield**
    - Linked to **34th Annual Cement and Concrete Science Conference (CCS2014)**
  - **11-12/06/2015 Austria, Vienna (upcoming)**
    - Linked to the **ICRM symposium**
  - **8-9/10/2015 Belgium Leuven (upcoming)**

- SHORT-TERM SCIENTIFIC MISSIONS
- TRAINING SCHOOLS
- PUBLICATIONS and DISSEMINATION

**www.norm4building.org**

# Scientific focus working groups



# Working Group 1

## ‘Data base with good practices’

### Norm4Building Database

a) **Criteria** for evaluation of practices were set.

b) Gathering information on NORMs currently used for building materials

c) Including **representative national surveys**

### Evaluation of practices

a)

b

**Information per entry**

General information:

- By-product name; Industrial sector
- Country
- Total amount of by-product [Mt], Number of surveyed samples
- References

Chemical features

Radiological features

- Activity concentration (terrestrial isotopes: Ra-226; Th-232, K-40)
- Activity concentration index

**Impact:**
**-NORM aspects are taken into account for reuse**
**-’Good practices database’ as guideline for reuse for industry**

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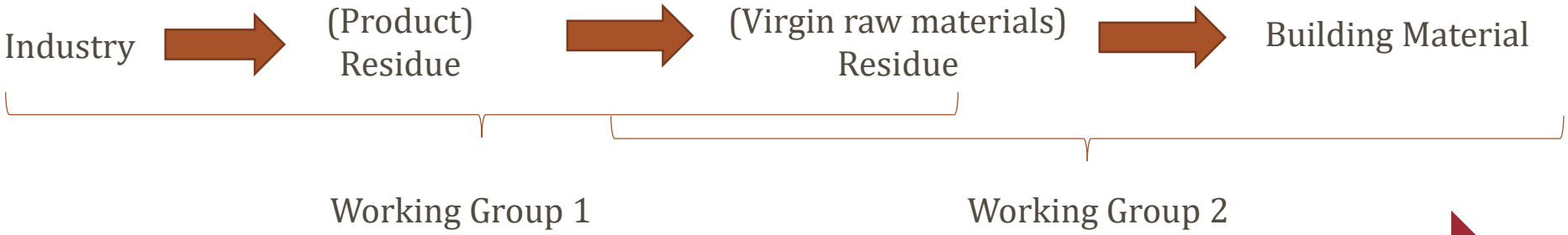
# Working Group 2

## ‘Options for new tailor-made building materials’




### Study new develop options

a) Analytical model with **relation** between **% of virgin raw materials substituted** and **radiological content**

b) Recommendations on use **secondary raw materials** in **geopolymers considering the radiological content**.

### Radiological content linked to…

**a)** **Pretreatment** of the raw materials

**b)** **Development and application** of the building material

c) Effect of **inherent and engineered properties**

# Working Group 3

## ‘Improve measurement capacity and standardisation’

### Validated (*in-situ*) measurement protocols for

a) Activity Concentration Index

b) Radon (possibly thoron) emanation and exhalation rate

**Intercomparisons** using several measurements protocols and instruments

### Towards standardisation

a) Proposal for a **calibration procedure**

b) Steps in the development of **standard materials**

### Towards certification

a) Factsheet for **unified certification procedure of construction materials**.


EURAMET
European Association of National Metrology Institutes

EMRP
European Metrology Research Programme
Programme of EURAMET

The EMRP is jointly funded by the EMRP participating countries within EURAMET and the European Union

# Working Group 4

## ‘Improving dosimetrical models’

### Improved (more realistic) dosimetrical models

For use of NORMs in

a) Cement
b) Concrete
c) Ceramics

Specific focus on use of NORMs in **geopolymers**.

### Evaluation of implementation on market.

a) **Round table discussions** with all stakeholders
b) **End-of-Life?**
   - Leachability

### Evaluation of legislation

a) **Impact EU-BSS**
b) Comparison of alternative national legislative scenarios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# Towards a more realistic assessment of the radiological impact when using NORM in building materials?

- Experimental building material related parameters
  ➔ modeling of impact NORM in building materials
  1. Gamma dose estimation
  2. Radon dose estimation
  3. Leachability/breakdown modelling of radiological and chemical impact

# 1. Gamma dose estimation:

✓ Input parameters:

1. Ra-226, Th-232 and K-40 activity concentration (measured)
2. Density, thickness, information on structure of dwellings

✓ Steps in the modeling approach:

3. Elaborated an index (ACI) accounting for density and thickness (done)
4. Further development of indexes in order to consider the actual structure of dwellings (all concrete but 1 wall in bricks, etc…) (future)

➔ Towards a more realistic screening, gamma dose modeling

Cristina Nuccetelli et al. Journal of Environmental Radioactivity 143 (2015) 70-75

# 2. Radon dose estimate

✓ Input parameters:

1. Ra-226 activity concentration (input from database)
2. Rn exhalation (new ISO standard)

✓ Steps in the modeling approach:

3. Rn exhalation modeling
   - ✓ Model of Rn exhalation for real life circumstances and important properties of building materials (decomposition, crack generation, porosity…)
4. Rn activity concentration by modeling to account for ventilation, dwelling size, convection, ….
5. Dose estimate

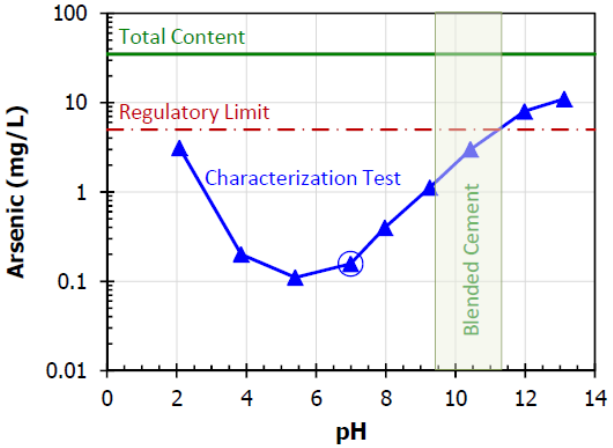
# 3. Leachability/breakdown modelling of radiological and chemical impact

✓ Input parameters:

| Leaching methods | Test | Standards | To investigate: |
|---|---|---|---|
| ➢ Method 1313 - Liquid-Solid Partitioning as a Function of Eluate pH using a Parallel Batch Procedure | pH dependence test | Construction products *(CEN/TS14429)* | In addition to other metals also: U, Ra, Pb and Po<br><br>(Council Directives 1998/83/EC and 2013/51/EURATOM) |
| ➢ Method 1314 – Liquid-Solid Partitioning as a Function of Liquid-Solid Ratio (L/S) using an Up-flow Percolation Column Procedure | Percolation test (End of life) | Construction products (CEN/TS16637-3) | |

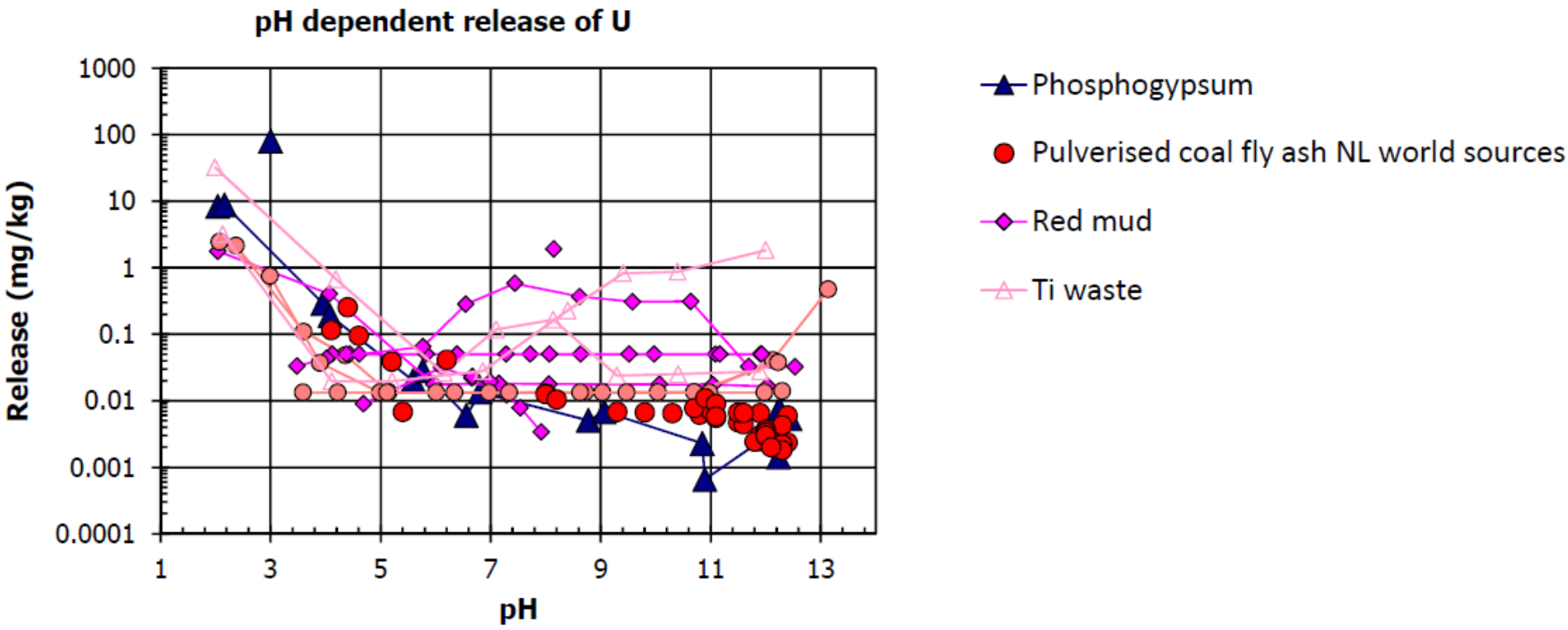
✓ Steps in the modeling approach:

– Modeling scenarios for important properties of building materials (mixtures, materials with different layers, carbonation, oxidation,…)




Hans van der Sloot and David S. Kosson, Presentation at WG 4 sub-group COST meeting, Hasselt 31/10/2014

# Leaching of uranium from NORM materials




Leaching behavior rather similar between different materials in spite of their difference in composition.

Hans van der Sloot and David S. Kosson, Presentation at WG 4 sub group COST meeting, Hasselt 31/10/2014

# Leaching studies

- Studies are available on heavy metals leaching from construction materials relative to the European drinking water Directive 98/83/EC
  - Example for paving concretes made with CEM III/A type cements (36–65% of slag) leaching tests (NEN 7345) show:
    - heavy metals leaching << parametric values (European Directive 98/83/EC)
    - The partial replacement of clinker with blast-furnace slag, within the limits defined in NBN EN 197-1 has little effect on the leaching behaviour of the concrete

- For the Leaching behaviour of natural occurring radionuclides relative to the COUNCIL DIRECTIVE 2013/51/EURATOM more study is required.

*P. Van den Heede, N. De Belie / Cement & Concrete Composites 34 (2012) 431–442

*COUNCIL DIRECTIVE 2013/51/EURATOM, 'laying down requirements for the protection of the health of the general public with regard to radioactive substances in water intended for human consumption'

# Towards a more realistic assessment of the radiological impact when using NORM in building materials?

- Experimental building material related parameters
  ➔ modeling of impact NORM in building materials
  1. Gamma dose estimation
  2. Radon dose estimation
  3. Leachability/breakdown modelling of radiological and chemical impact

Input for (expanded) life cycle assessment (LCA)

- Taking into account NORM aspect in LCA

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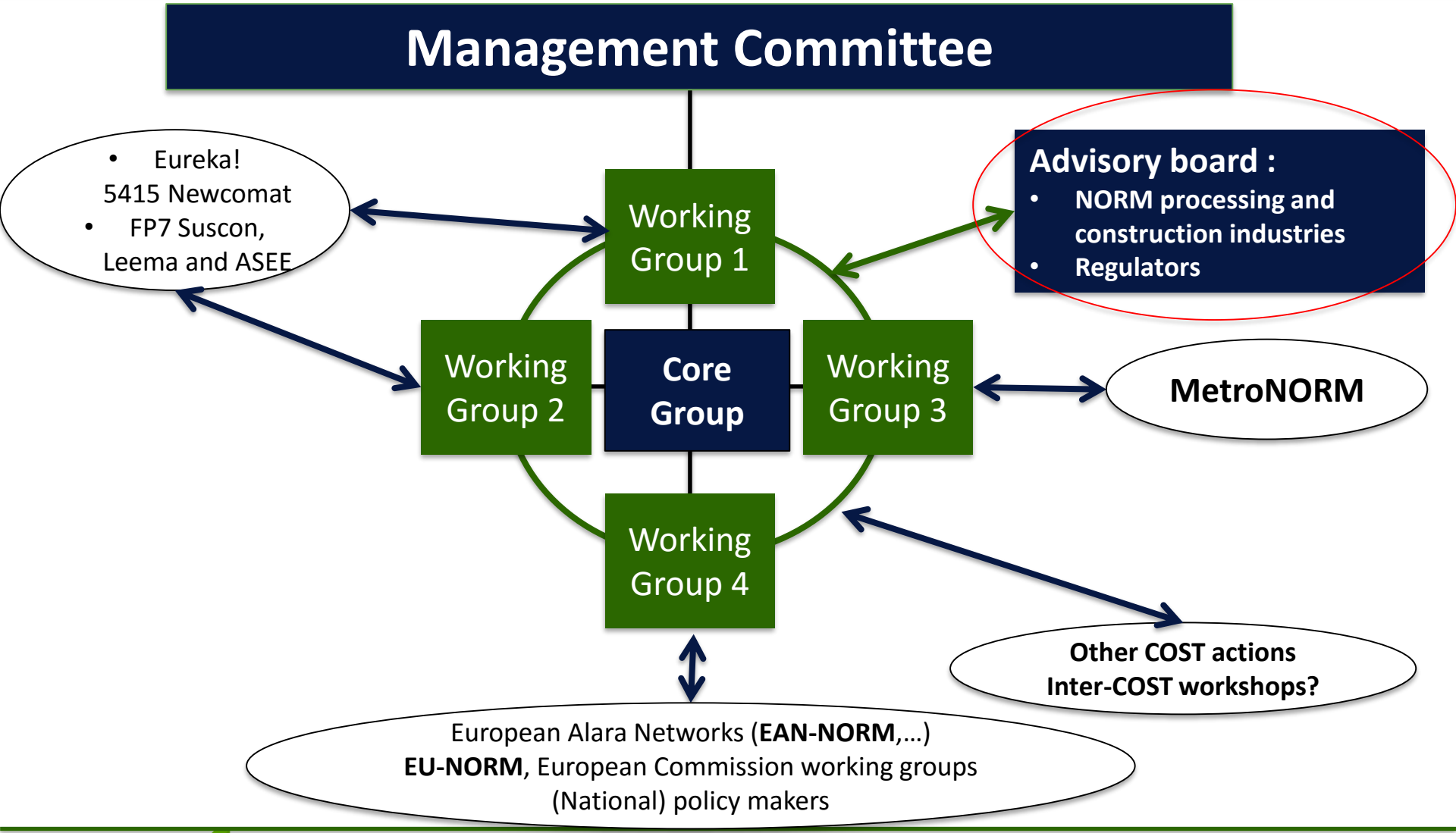
3. **Collaboration opportunities**

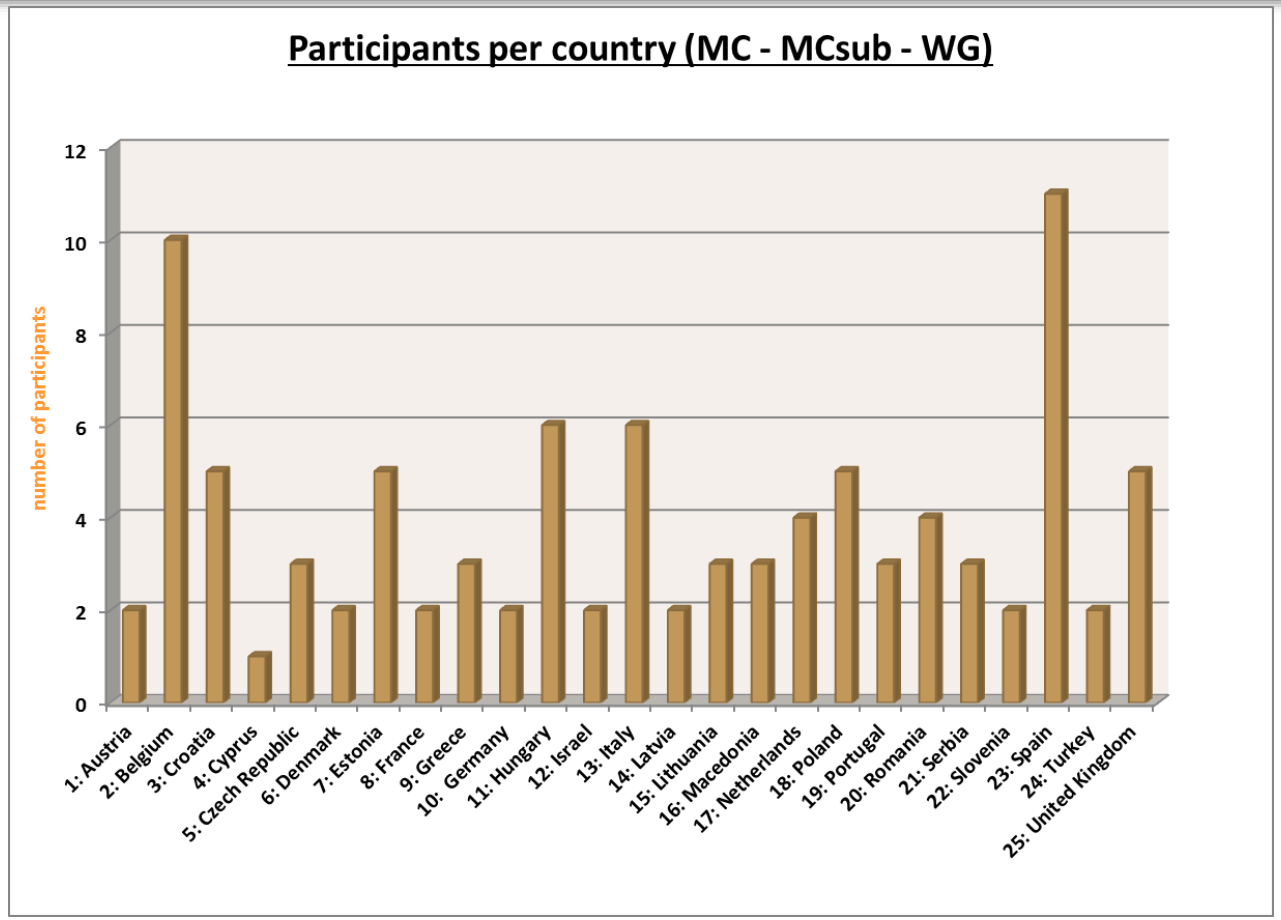
# Organization – collaboration



# Collaboration with industry

- Development of research and innovation projects to valorize NORM residues of industrial partners
- Workshops and round tables specifically for training of participants from industry
- Industrial partners get access to database of good practices

# Collaboration in the Cost network




- 25 European countries + European Commission
- A strong variety of (so far) about 96 experts

# Current status of the COST Network