

INTRODUCING WP MOGARE

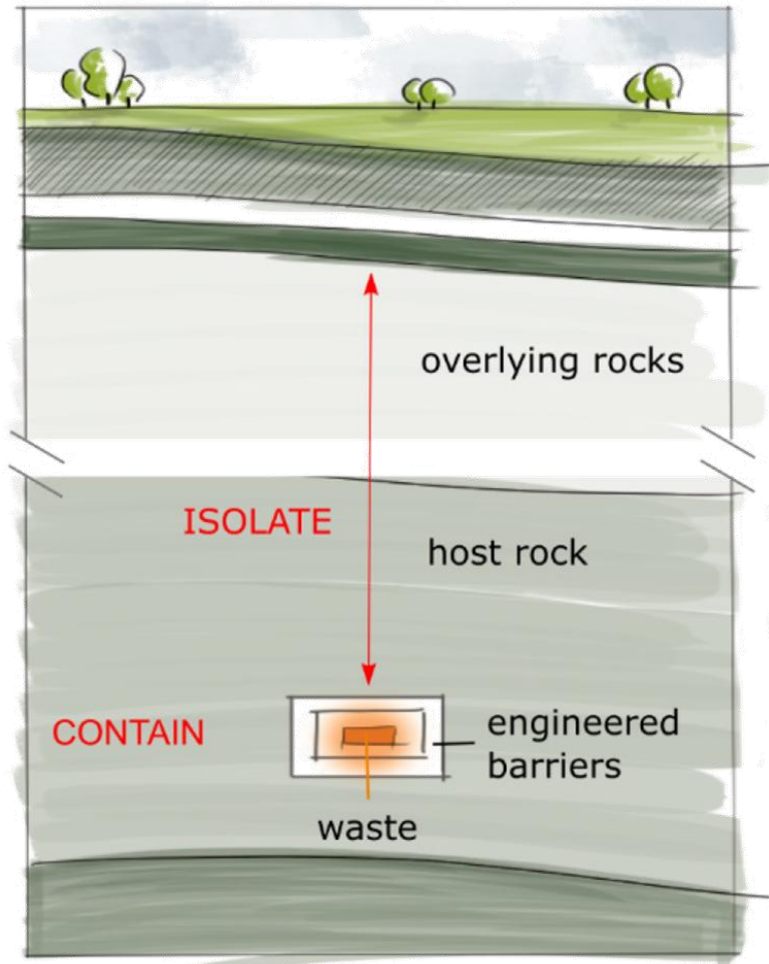
Modelling of Gas Behaviour and Migration at the Repository Scale for Storage/Disposal

D. Cavalcanti, F. Collin, S. Olivella, P. Ormai, M. Pitz, Z. Saâdi,
E. Toprak, L. Urpi, J. Wendling, and G. Ziefle



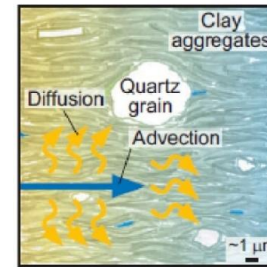
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MULTI-BARRIER SYSTEM AND THE IMPACT OF GAS

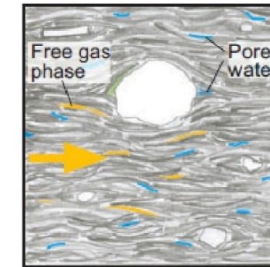


Levasseur et al. (2024)

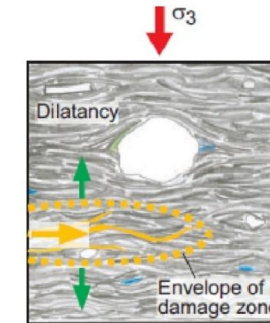
(a) Phenomenological description



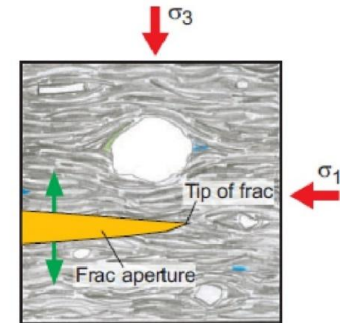
Advection & diffusion of dissolved gas



Visco-capillary flow of gas and water phase ("two-phase flow")

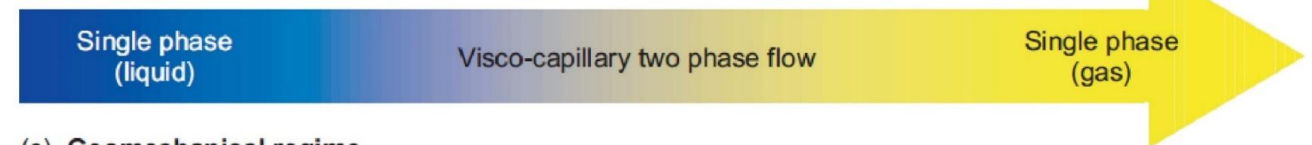


Dilatancy controlled gas flow ("pathway dilation")

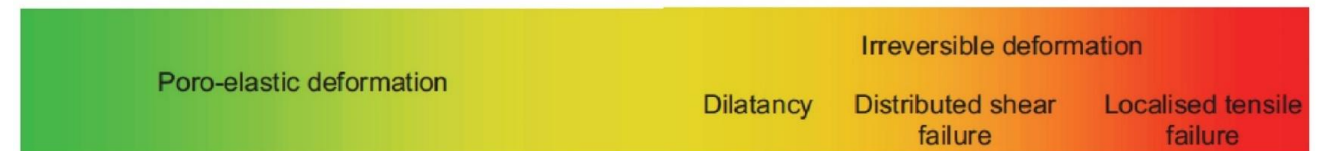


Gas transport in tensile fractures ("hydro-/gasfrac")

(b) Transport mechanisms



(c) Geomechanical regime



Marschall et al. (2005)

IDENTIFYING THE GOVERNING PARAMETERS

Gas pressure evolves over time with the ratio

Gas release rate

Gas evacuation rate

scaled by the

Storative capacity

Gas release rate

Controllable by design

- Amount of metallic components
- Type of metal alloy
- ...

Given by nature

- Water chemistry
- Water availability
- ...

Gas evacuation rate

Controllable by design

- Effective gas transmissivity in EBS
- Water saturation and retention in EBS
- ...

Given by nature

- Gas transmissivity of EDZ and host rock
- Host rock porosity
- Hydrogen solubility and diffusivity
- ...

Storative capacity

Controllable by design

- Excavated volume
- Backfill porosity
- ...

Given by nature

- Hydrogen solubility and diffusivity
- Host rock porosity
- ...

List is not exhaustive – but it shows: Some factors can be controlled, some cannot. All must be understood, and their impact quantified at repository scale.

AS COMPLEX AS NECESSARY — AS SIMPLE AS POSSIBLE

Complexity

- Complete architecture of the repository
- Properties of the different materials
- Coupled multi-physical processes



Computational tractability (simplifications)

- Process parametrisation
- Mesh generation
- Numerical methods

MOGARE addresses this balance through three aims

1 Process representativity

- Which processes and **EBS elements** must be represented at repository scale?
- Which can be **neglected or simplified** without losing relevant gas transport processes?

2 Upscaling

Transparent links between

- **Laboratory observations** (e.g. localised gas advection)
- **Model set-up** (Constitutive relationships...)
- **Repository-scale** performance assessment

3 Design & safety relevance

Methodologies to

- Make **large-scale modelling** feasible
- Support **repository design** optimisation
- Improve **confidence** in long-term safety assessments

CATALOGUE OF RESEARCH QUESTIONS (AS PART OF TASK 3)

Propose a model simplification



Pair it with a research question



Test it against a full reference model



Derive best-practice recommendations

Geometric

- Can far-field host rock or over-/underlying units be replaced by **Robin boundary conditions**?
- How far can **seals** and **galleries** (backfill, liner, EDZ) be homogenised?
- Do **preferential pathways** along barrier interfaces change the pressure build-up?
- ...

Physical

- Can **thermal processes** be neglected for gas transport?
- **Gravity**: hydrostatic vs. gas-phase contribution
- Impact of **water consumption** by corrosion, resaturation rate and water retention model
- ...

Numerical

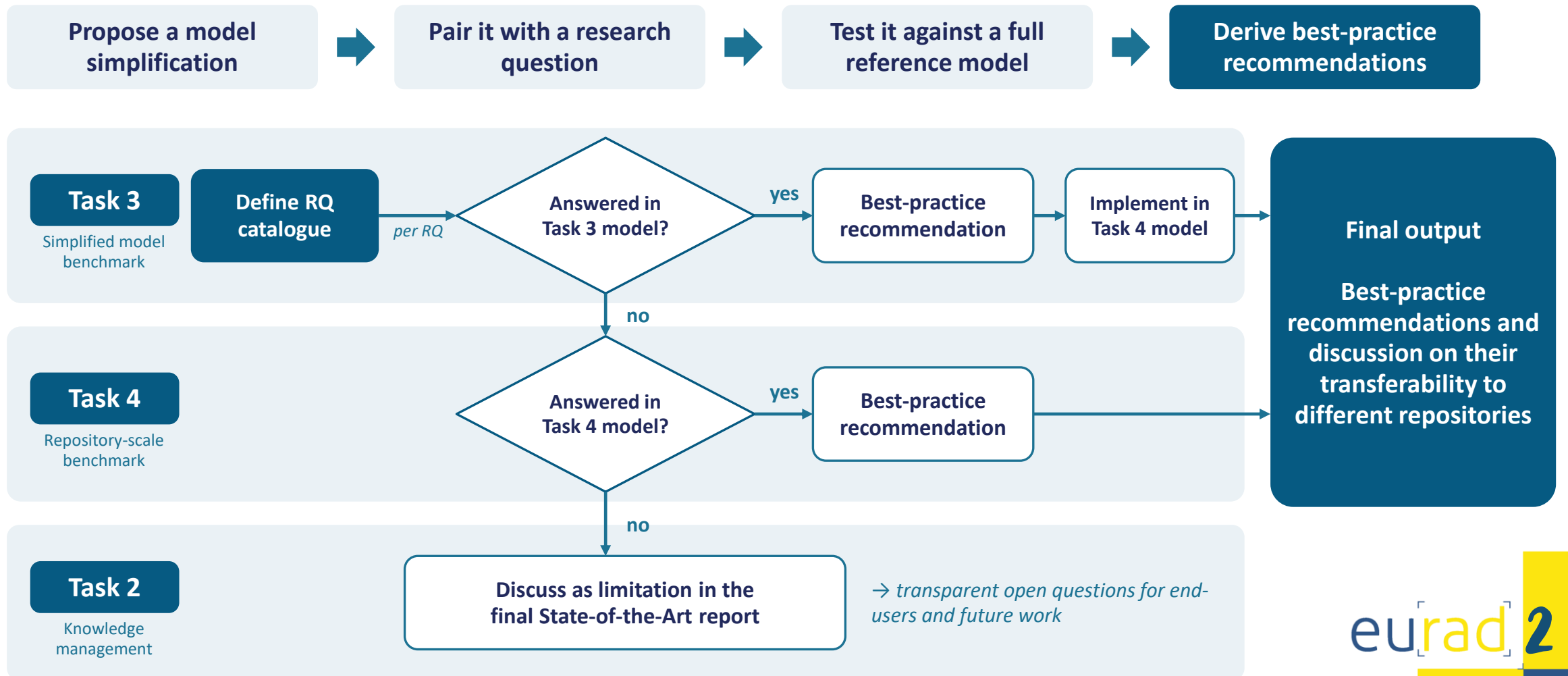
- **Finite volumes vs. finite elements**: must the full repository volume be meshed?
- Required **mesh refinement** around seals and galleries
- Which **degree of homogenisation** keeps safety indicators intact?
- ...

Compared on: max. gas pressure and its timing · pressure gradient and gas flow across seals and galleries · integrity indicators · radionuclide transport

Open draft – input from WMOs, TSOs, REs and other WPs welcome

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CATALOGUE WORKFLOW // PER RESEARCH QUESTION

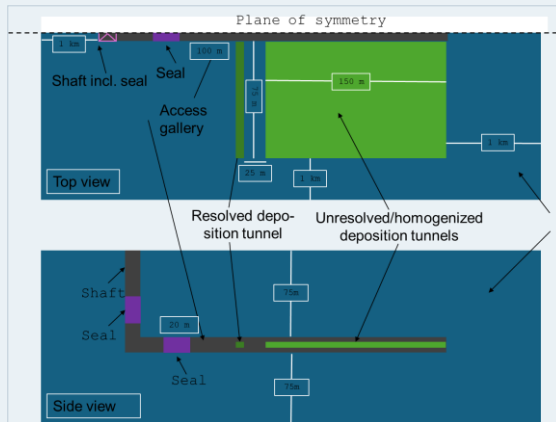


FROM STYLISTED TO REPRESENTATIVE

Task 3

Simplified model benchmark

Lead: ULiège (Co-Lead: PSI)



Generic half-repository (draft geometry)

- **1D warm-up:** align the codes on a simple drift + host-rock column
- **Generic repository:** one resolved tunnel, homogenised tunnels, galleries, seals, shaft
- **TH2 physics:** water, hydrogen, heat
- **Every partner** runs the reference, then catalogue studies + sensitivities

**validated
simplifications**

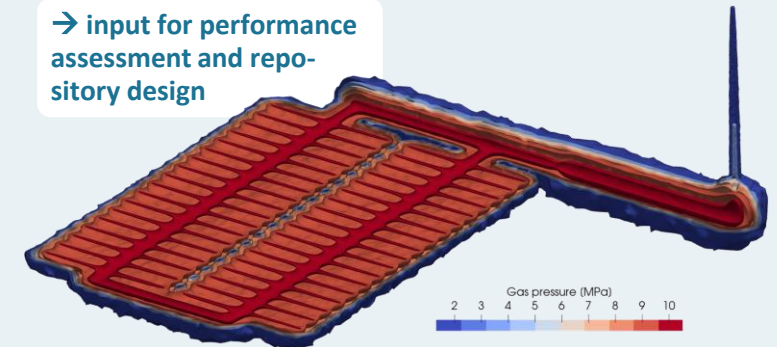
Task 4

Representative repository-scale benchmark

Lead: UPC/CIMNE (Co-Lead: ANDRA)

- Catalogue studies at **repository-representative scale**
- Studies needing the **full repository geometry**
- **Targeted sensitivity** analyses

→ input for performance assessment and repository design



Earlier large-scale study (Pitz et al., 2026)

Key outcome: not only a benchmark, but a jointly agreed hierarchy of modelling assumptions – what must be resolved and what can be coarsened, agreed by modellers, WMOs and TSOs

OVERVIEW // WORK PACKAGE STRUCTURE

Task 1 Management / Coordination

Lead: BGR (Co-Lead: ANDRA, PSI, ASNR)

- WP Board in cooperation with WP partners defines and structures a catalogue of studies for the consortium to discuss/execute

Task 2 Knowledge Management

Lead: ASNR (Co-Lead: tbd)

- SotA reports, built on previous work and kept current with end-user needs
- **Training materials, a doctoral school and webinars;** data on ZENODO

Task 3 Research questions and simplified modelling

Lead: ULiège (Co-Lead: PSI)

- Establish common reference model with results from every partner and discuss potential differences
- Accompanying sensitivity studies — targeted or statistical, per feasibility

Task 4 Representative repository-scale modelling

Lead: UPC/CIMNE (Co-Lead: ANDRA)

- Run catalogue studies at repository-representative scale for performance assessment
- Run individual studies requiring full repository geometry

THANK YOU VERY MUCH FOR YOUR ATTENTION!



References:

Levasseur, S., Collin, F., Dymitrowska, M., Harrington, J., Jacobs, E., Kolditz, O., Marschall, P., Norris, S., Sillen, X., Talandier, J., Truche, L., Wendling, J. (2024): State of the art on gas transport in clayey materials – update 2023. Deliverable D6.2 of the HORIZON 2020 project EURAD, Work Package Gas. EC Grant Agreement no. 847593.

Marschall, P. et al. (2005): Characterisation of gas transport properties of the Opalinus Clay, a potential host rock formation for radioactive waste disposal. Oil & Gas Science and Technology, 60(1), 121–139.

Pitz, M., Zieflé, G., Kunz, H., Grunwald, N., Nagel, T., Maßmann, J. (2026): A numerical large-scale investigation of gas transport processes in a generic nuclear waste repository in argillaceous porous media. Environmental Earth Sciences, 85, 191. <https://doi.org/10.1007/s12665-026-12895-4>

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