# DIAMONDS

Advisory Committee – 26 February 2024

# Welcome

Advisory Committee

# Agenda

- **9.00**: Site visit @ Fluxys gas storage
- ***12.00**: Lunch*
- **13.00**: Welcome & Introduction to DIAMONDS
- **13.30**: Parallel sessions
  - 13.30: Parallel sessions – round 1
  - *14.45: Coffee break*
  - 15.00: Parallel sessions – round 2
- **16.15**: Wrap-up
- *16.30: Coffee to end the day*

# Introduction

The DIAMONDS project

Scientific part

Valorization part

# DIAMONDS

**D**ynamic **I**ntegrated **A**ssessment **M**ethods f**O**r the sustai**N**able **D**evelopment of the **S**ubsurface

The Campine basin

# Project team

University of Antwerp | Faculty of Business and Economics

Prof. Dr. Tine Compernolle

Universiteit Antwerpen | Faculteit Sociale Wetenschappen

Prof. Dr. Anne Bergmans

Universiteit Antwerpen | Faculteit Toegepaste Ingenieurswetenschappen

Dr. Matti Buyle

UNIVERSITEIT GENT | FACULTY OF ECONOMICS AND BUSINESS ADMINISTRATION

Prof. Dr. Brent Bleys

UNIVERSITEIT GENT | FACULTY OF SCIENCES

Prof. Dr. Thomas Hermans

TU Delft | Civil Engineering and Geosciences

Prof. Dr. Alex Daniilidis

Prof. Dr. Phil Vardon

Dr. Hanne Lamberts-Van Assche

Kyra Verheyen

Alexander Van Overmeiren

Alexandra Vancammeren

Carolin Wallmeier

PhD researchers

natural sciences .be

Dr. Kris Piessens and Dr. Kris Welkenhuysen

# Related ongoing research projects

Luka Tas

Improving Aquifer Thermal Energy Storage Systems Design through Advanced Hydrogeological Uncertainty Quantification (ATES2.0). FWO PhD fellowship.

Mujtaba Masroor

Jose Rodriguez

Multidisciplinary Assessment of Subsurface Interactions: the fundamentals (MASSIF). FWO research project.

Adithya Eswaran

Sustainable management of geological resources. UAntwerp BOF

Geological Economics
FED-tWIN

# VPO government assignment

## Maatschappelijke impact van het gebruik en beheer van de Vlaamse diepe ondergrond (Jan 2023 – Jun 2024)

- **Doel van de opdracht: duurzaam beheer van de ondergrond?**
  - Indicatoren en randvoorwaarden voor duurzame ontwikkeling van de ondergrond
  - Geologische mogelijkheden en impacts
  - Bovengrondse milieu-economische en sociale effecten

- **3rd Stakeholder workshop 26 March 2024**
  - **Stakeholder mapping**
  - **Internationaal beleid**
  - **Resultaten impactanalyse voor verschillende beleidsscenario's**

Universiteit Antwerpen

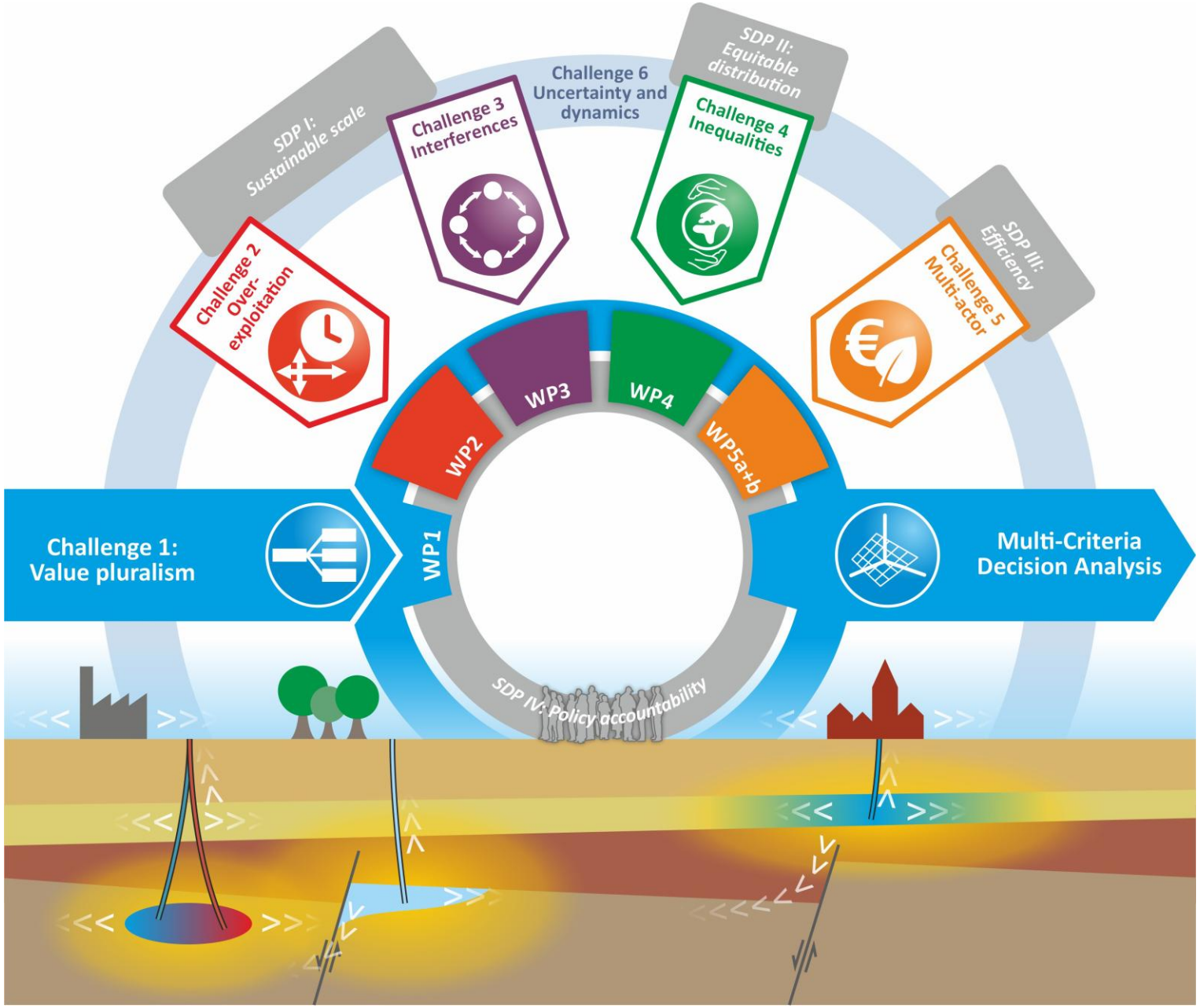
Geological Survey of Belgium

museum

Vlaanderen
is omgeving

# DIAMONDS

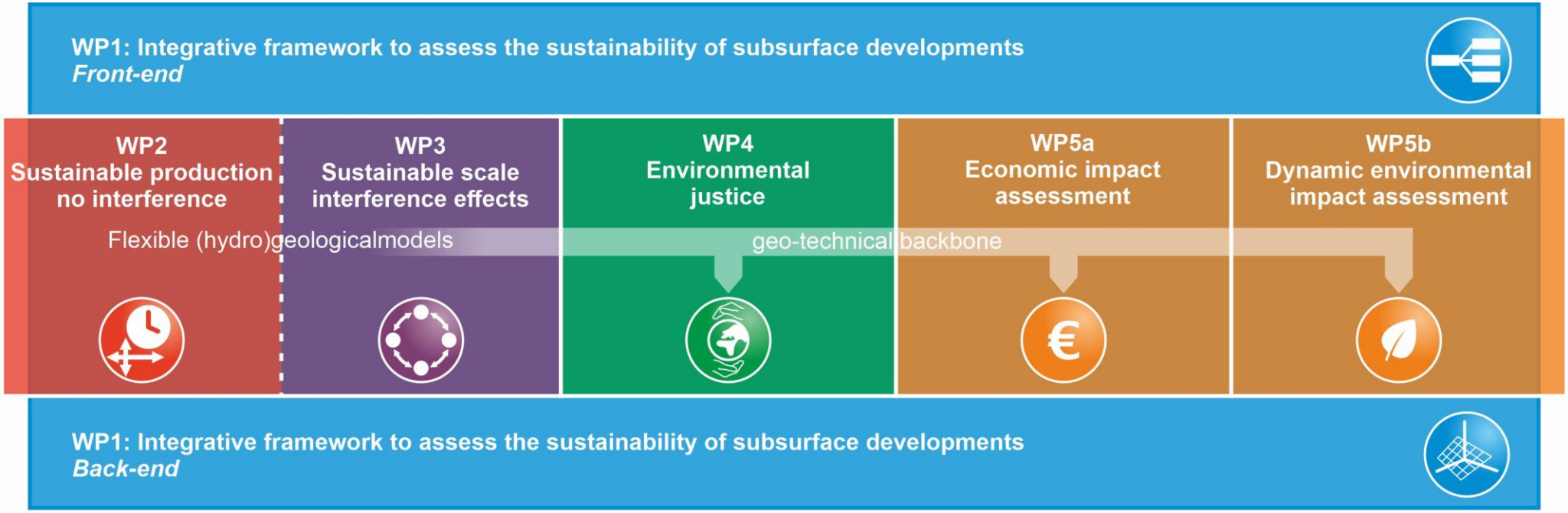
## Scientific part




# DIAMONDS

- PC&I framework to evaluate the sustainability of subsurface use
- Long term (overexploitation?)
- Multifunctional use (interference?)
- Social impact (aspects of justice/inequalities?)
- Economic and environmental impacts (multi-actor?)
- Dynamics and uncertainties?
- Integration?

# DIAMONDS






**Linking to the objectives**

- O1: to understand what sustainable management of geological resources involves and how to measure it
- O2: to develop flexible (hydro)geological models to determine hydrogeological threshold values for the identified sustainability indicators
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- O6: to integrate the calculated environmental and economic values together with hydrogeological values into a multi-dimensional decision support framework

# DIAMONDS

## Valorization part

# DIAMONDS - Advisory Committee





















# DIAMONDS - Advisory Committee

- Utilization objectives
  - The creation of a shared vision on the sustainable development of the Campine Basin
  - To provide insights for public policy advisors to help them improve the regulatory framework to manage potential interference effects between subsurface activities within the Campine Basin for the long-term, treating all subsurface activities on an equal basis
  - To create a methodological decision support framework to help stakeholders understand how the use of the Campine Basin can be matched with above-ground sustainability objectives.

# DIAMONDS - Advisory Committee

- Utilization strategy

Year 1-2: creation of a general framework that synthesizes the indicators of sustainable subsurface development

Year 2-3: model testing, applications in the practice field, and mutual learning

Year 3-4: co-creation of knowledge transfer tools

- AC member involvement

Semi-structured interviews | meetings | workshops

# This afternoon

- Workshop – parallel sessions
- Case studies on multifunctional use
  - Shallow: groundwater extraction and aquifer thermal energy storage
  - Deep: geothermal energy extraction and gas storage
  - Deep: long term geothermal (multiple geothermal project) → not today

- PC&I and CLD
- AC meeting report + outcomes (PC&I and CLD)
- Invitation to further have (bilateral) discussions on PC&I and CLD
- Suggestions? Specific questions?

# Case studies

## Multifunctional subsurface use

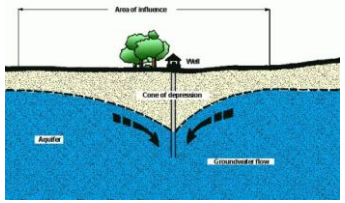
Case study 1: groundwater extraction & ATES

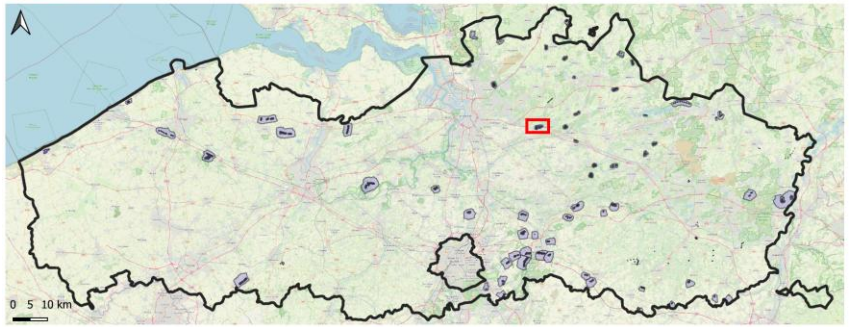
Case study 2: deep geothermal energy & gas storage

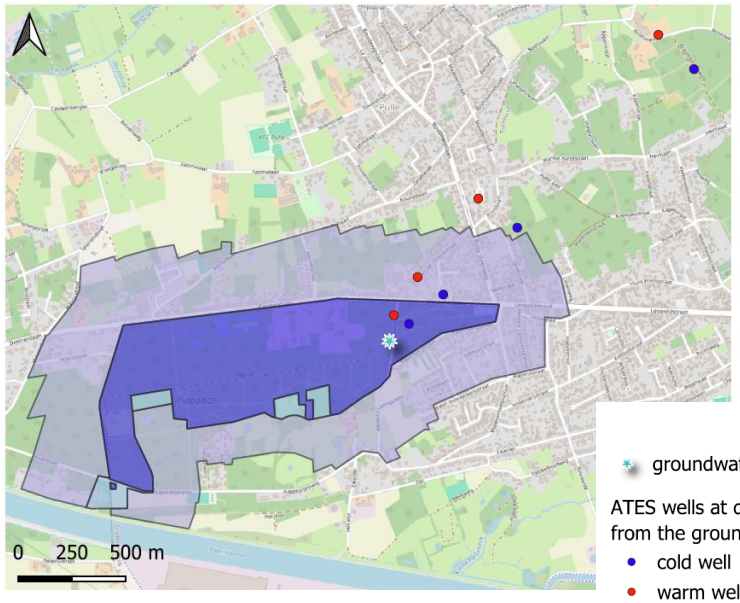
# Case study 1: Groundwater extraction & ATES

## Groundwater extraction for drinking water supply


Groundwater protection zones
- type I
- type II
- type III



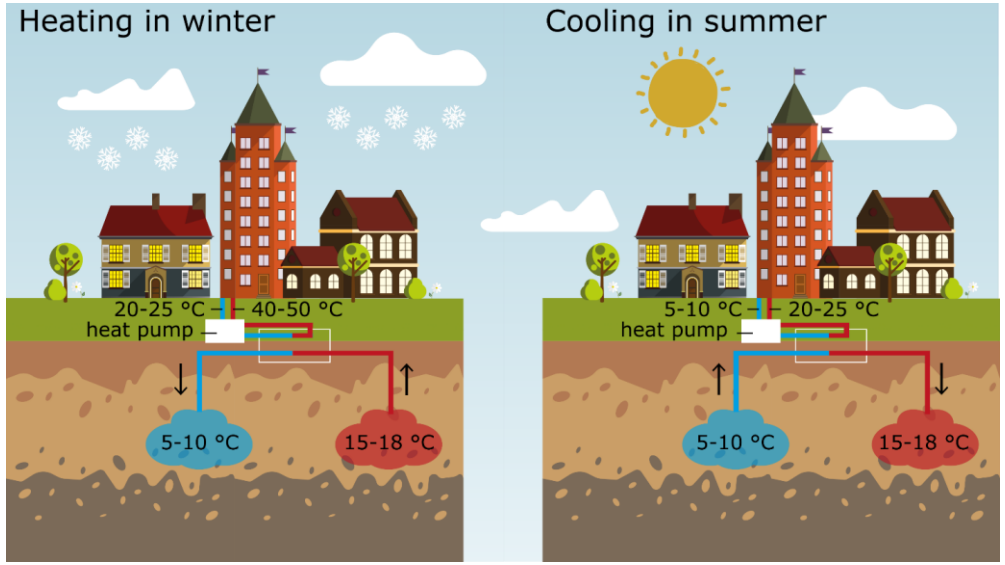




- groundwater extraction

ATES wells at different distances from the groundwater extraction:
- cold well
- warm well

## What happens when ATES is near or within the groundwater protection zones?

## Aquifer Thermal Energy Storage (ATES)




| 24 hours advection distance | 60 days advection distance | 1 year advection distance | 5 years advection distance |
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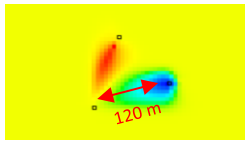
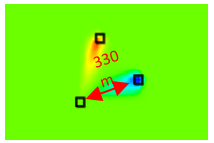
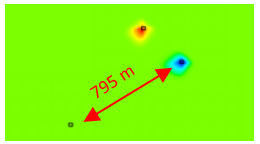
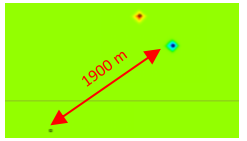
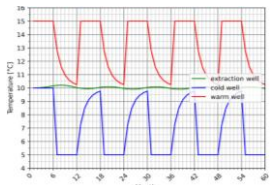
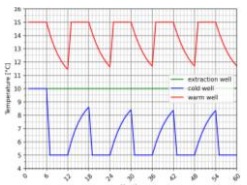
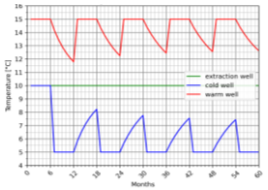
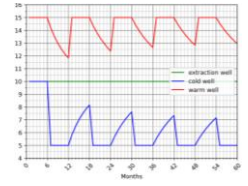
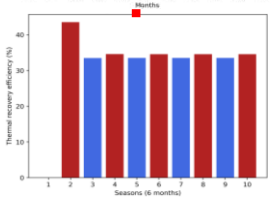
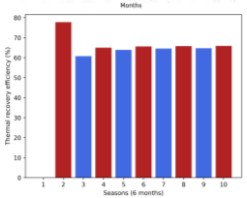
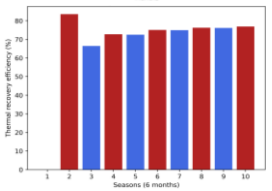
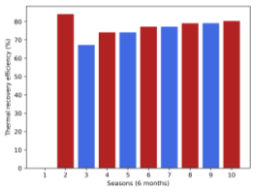
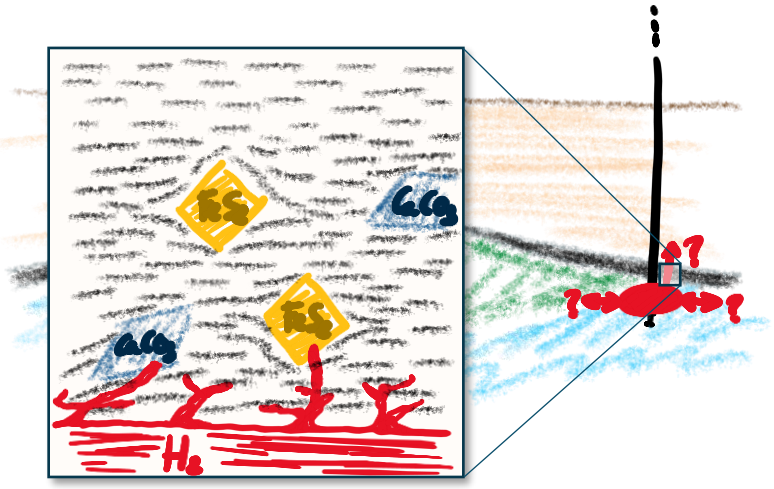
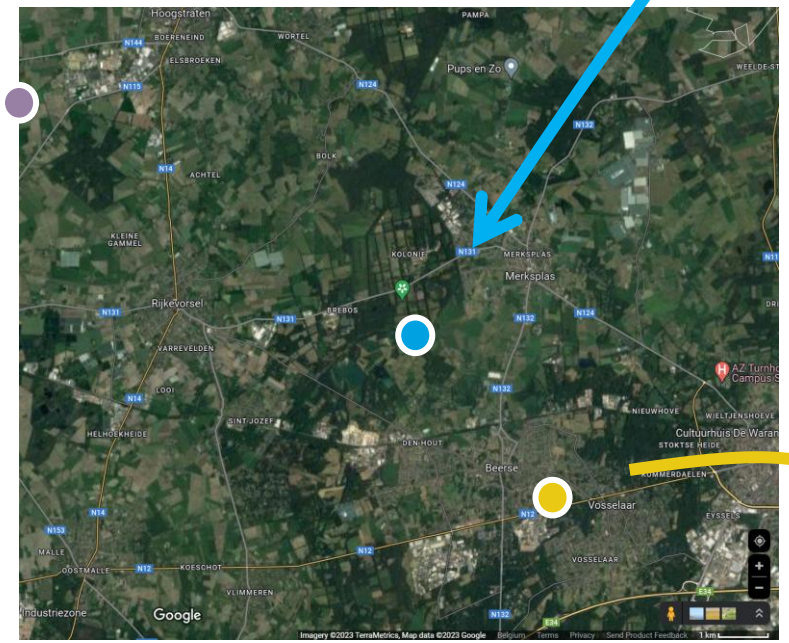
|   |   |   |   |
|  |  |  |  |
|  |  |  |  |

# Case study 2: Deep geothermal energy & gas storage

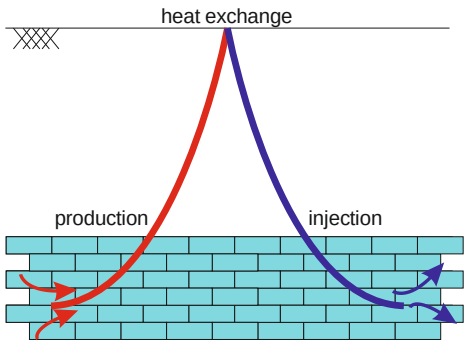
**Loenhout:**
Storage of natural gas
& pilot test storage of hydrogen




**Merksplas:**
monitoring interference effects




**Beerse:**
Geothermal doublet



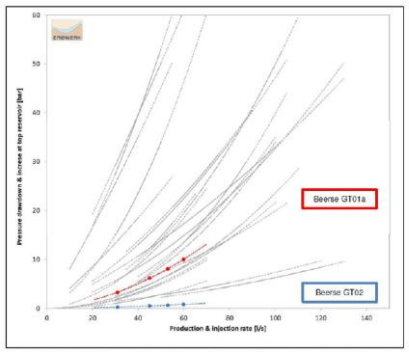




Fig. 1: Comparison of the productivity of the Beerse GT01a well (red curve) and the injectivity of the Beerse GT02 well (blue curve) with productivity and injectivity curves from geothermal wells in the Molasse basin (carbonate reservoir).

# Parallel sessions

Application of the PC&I framework for sustainable subsurface management

Development of a Causal Loop Diagram (CLD)

# Sustainability? → PC&I framework

→Principles: these are the fundamental rules that a subsurface use must meet to be considered sustainable. Principles are formulated as a commandment. In this way, principles define sustainable use of the subsurface.

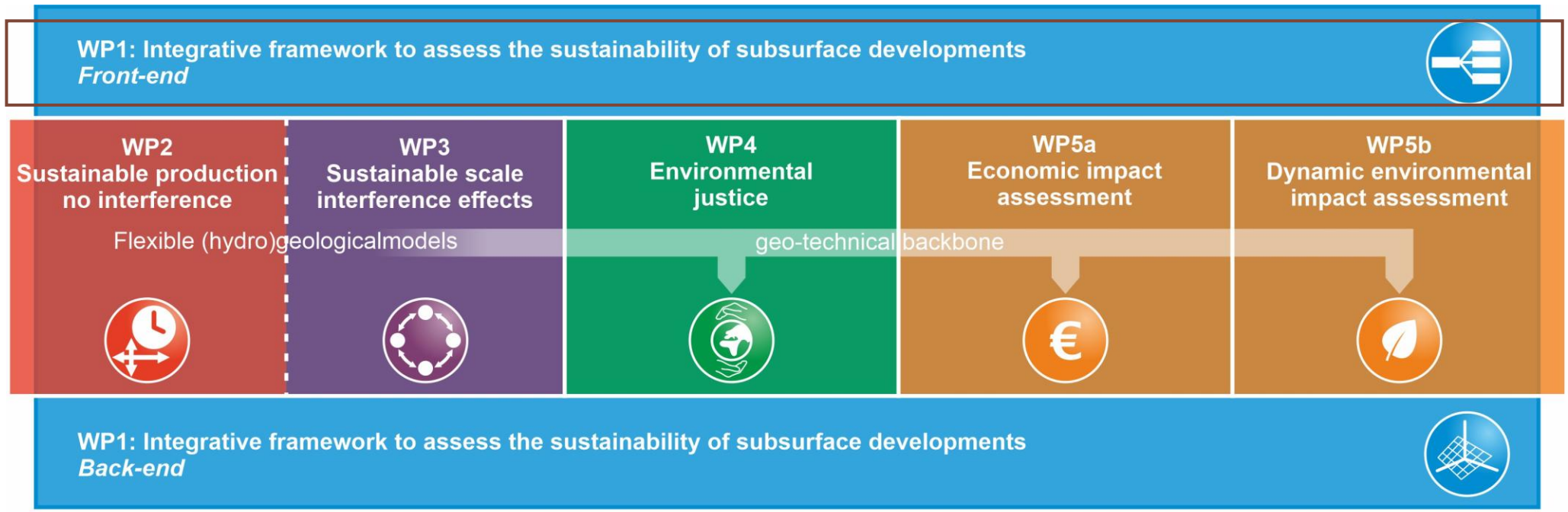
→Criteria: each principle may contain several criteria. These criteria are the conditions that must be met to satisfy the principle with which they are associated. The criteria are formulated to enable judgment.

→Indicators: indicators are the measurable variables that make it possible to assess whether or not a particular criterion or precondition is met. Indicators can be quantitative, qualitative, continuous or discrete. Generally, the definition of indicators involves the definition of a standard/threshold that sets a boundary between compliance and noncompliance with a criterion, and the definition of a method, tool or instrument used to measure the indicator.

# The PC&I framework

- VPO assignment: a general PC&I framework for the sustainable management of the deep subsurface was developed

- For each case study: to apply this PC&I framework to evaluate
  - whether and
  - under which conditions the multifunctional use of the subsurface can be considered sustainable

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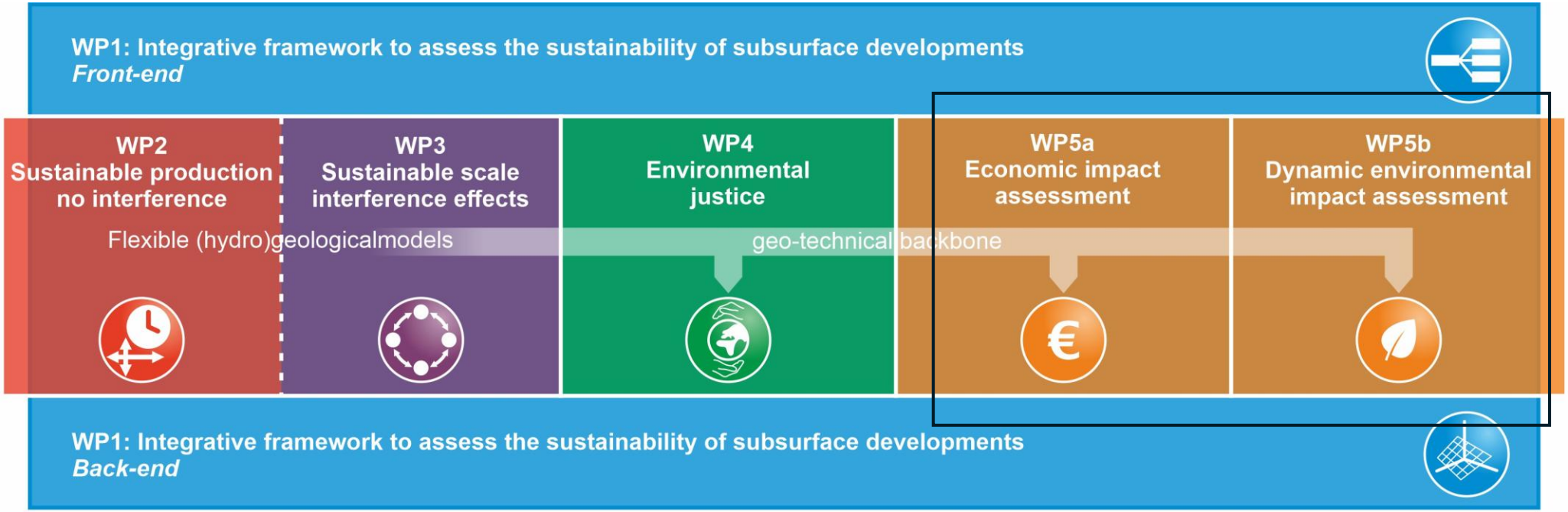
# Causal loop diagram (CLD)

- Geological resources are considered a geosystem which interacts with the above-ground environment (also a system)
- What is a system? A system is a network of multiple variables that are connected to each other through causal relationships
- System thinking? A common concept  for understanding how causal relationships and feedbacks work in an everyday problem
- CLD: to explicitly map the understanding of the problem and making it transparent and visible for others

→To understand relationships between the system components

→To surface sustainability challenges

→To look for leverage/solutions

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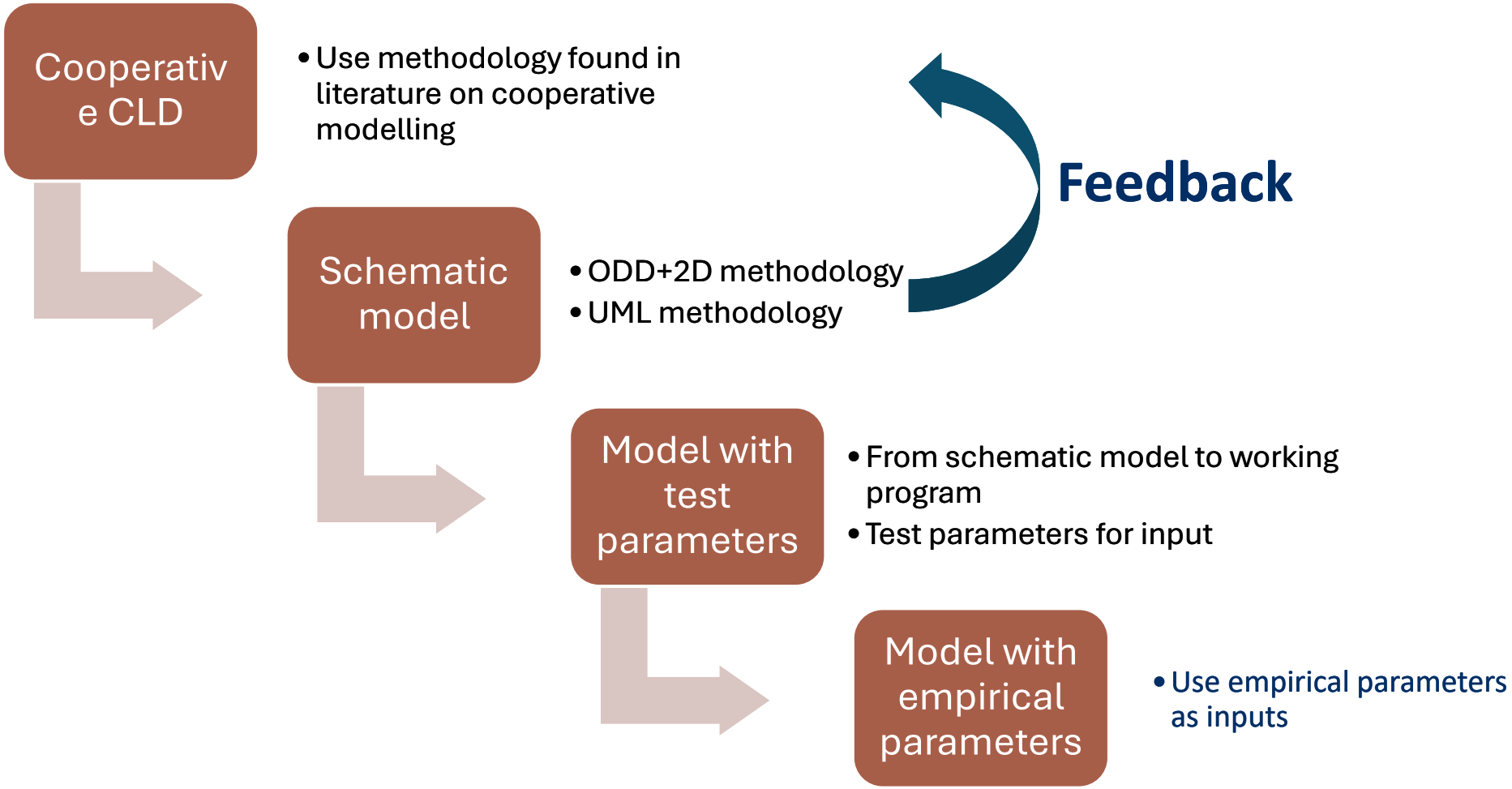
# Causal Loop Diagrams (CLDs)



# Parallel sessions

Application of the PC&I framework for sustainable subsurface management

Development of a Causal Loop Diagram (CLD)

# Parallel sessions

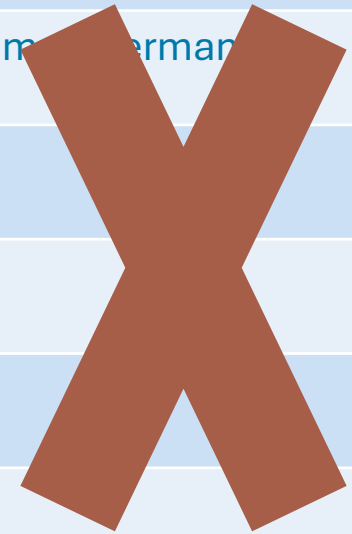
- Case study 1: groundwater extraction & ATES
- Case study 2: deep geothermal energy & gas storage

➔Apply PC&I to Case study 1 & 2

➔Apply CLD to Case study 1 &2

# Parallel sessions – Round 1 (13.30)

| PC&I – Case study 1 | PC&I – Case study 2 | CLD – Case study 1 | CLD – Case study 2 |
|---|---|---|---|
| Hanne Lamberts | Alexandra Van Cammeren | Alexander Van Overmeiren | Matti Buyle |
| Tine Compernolle | Anne Bergmans | Thom erman | José Rodriguez |
| Luka Tas | Kris Piessens | | Kris Welkenhuysen |
| Ann Elen | Carolin Wallmeier | | Alex Daniilidis |
| Tahnee Van Steenbrugge | Stijn Bos | | Dominique Ceursters |
| | Laurent Wouters | | Johanna Van Daele |
| | Helga Ferket | | Boris Dehandschutter |
| | Tinne Snoeijs | | Stijn Kuypers |
| | Hans Veldkamp | | Frans Denayer |



# Parallel sessions – Round 2 (15.00)

| PC&I – Case study 1 | PC&I – Case study 2 | CLD – Case study 1 | CLD – Case study 2 |
|---|---|---|---|
| Hanne Lamberts | Alexandra Van Cammeren | Alexander Van Overmeiren | Matti Buyle |
| Anne Bergmans | Tine Compernolle | Thomas Hermans | José Rodriguez |
| Brent B | Kris Welkenhuysen | Luka Tas | Kris Piessens |
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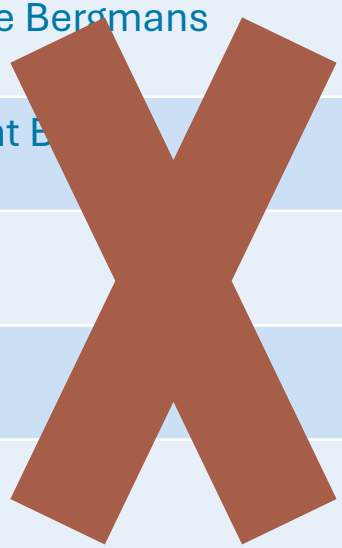

# PC&I

Advisory Committee – 26 February 2024

# Instructions

- **Principles, Criteria and Indicators (PC&I) framework**
  - Principles: relate to the multiple functions of the subsurface
  - Criteria: conditions that must be met to comply with a particular principle
    - Criteria are more concrete than principles and easier to assess and link to indicators
  - Indicators: variables of any kind that can be used to assess whether a particular criterion has been met (or not)
    - Variables must be measurable to assess if criteria is met (or not)
  - Goal of PC&I: evaluating the sustainable management of subsurface activities
- Principles already defined → see poster

# Instructions

- **Today: look at criteria and answer the following questions in group**
  a) Are the criteria relevant?
  b) How can the criteria be translated to the case?
  c) Are there criteria missing?

- **Look at principle 1, 2 & 3 for one case** → pay attention to the time!
  - Round 1: start with principle 1
  - Round 2: start with principle 3

- **1 hour 15 minutes** for the case → 20-25 minutes per principle

# Wrap-up

# Thank you!