# Towards a better understanding of risks and benefits of geothermal fluid properties:

## Insights form the projects REFLECT and CRM-geothermal

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30.03.2023

GFZ
Helmholtz Centre
Potsdam

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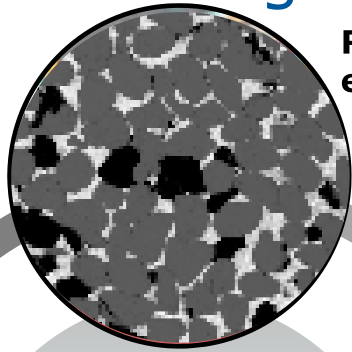
# Relevance of fluid research for geothermal energy

**Reservoir engineering**

Fluid reactions affect reservoir permeability



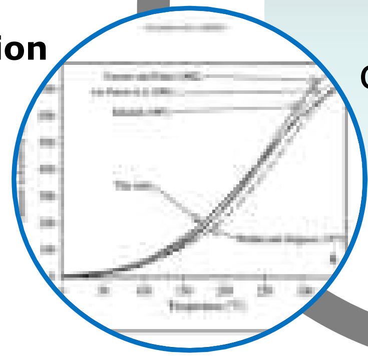
Bundesverband Geothermie.de

Fluid

carries heat

**Exploration**

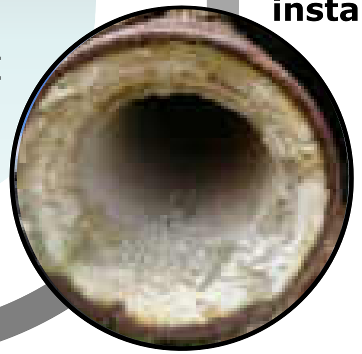
Fluid ingredients reveal reservoir temperature and origin



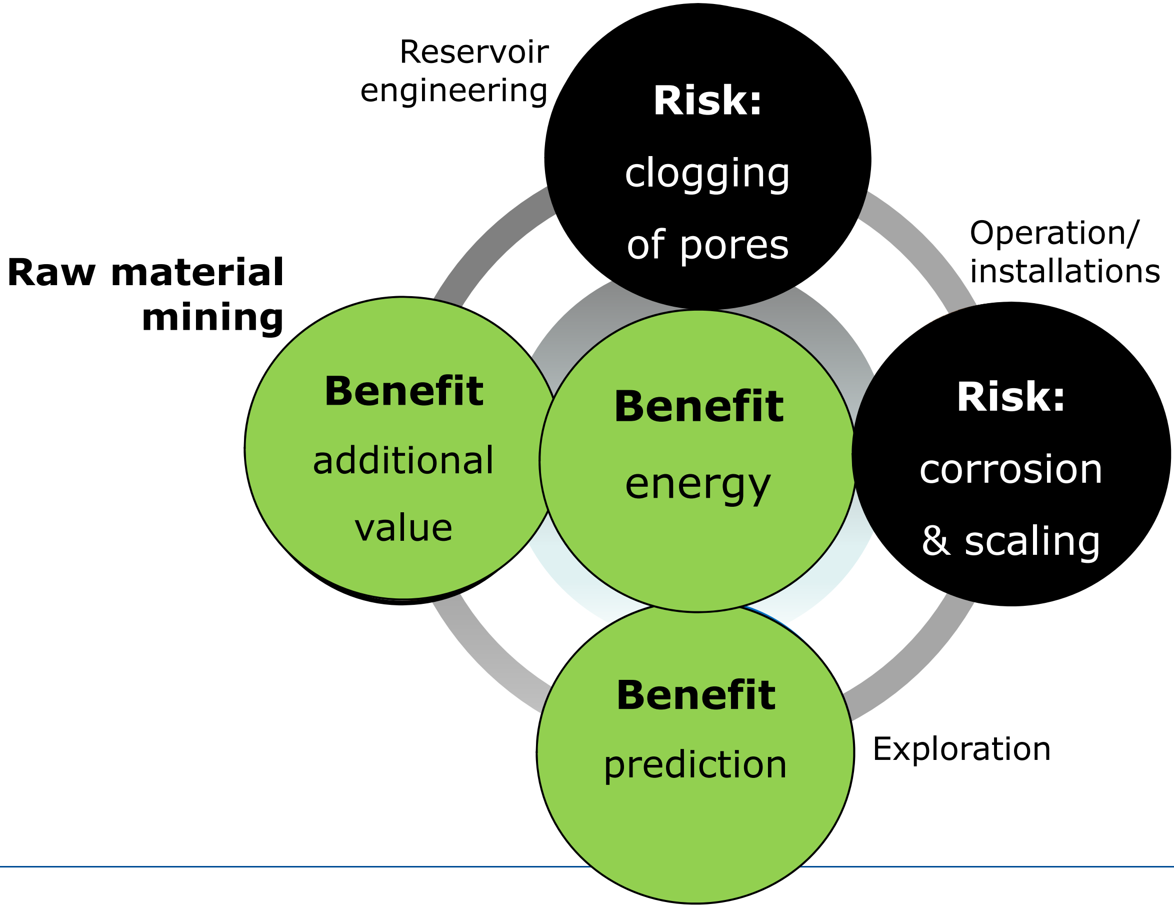
Gunnarsson, I. and Arnórsson, S., 2000

**Operation/ installations**

Fluid reactions cause corrosion and scaling;
Health and safety issues



# Geochemical **risks** and **benefits** utilizing deep fluids

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# REFLECT

## Redefining geothermal fluid properties at extreme conditions to optimise future geothermal energy extraction

Simona Regenspurg, Katrin Kieling

www.reflect-h2020.eu

Twitter: @reflect_h2020

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 850626

# Call & Partners

Call:

EU Horizon 2020 LC-SC3-RES-14-2019: „Optimising manufacturing and system operation”

Duration: 3 years; start 1.1.2020, Coordination: GFZ

Partner


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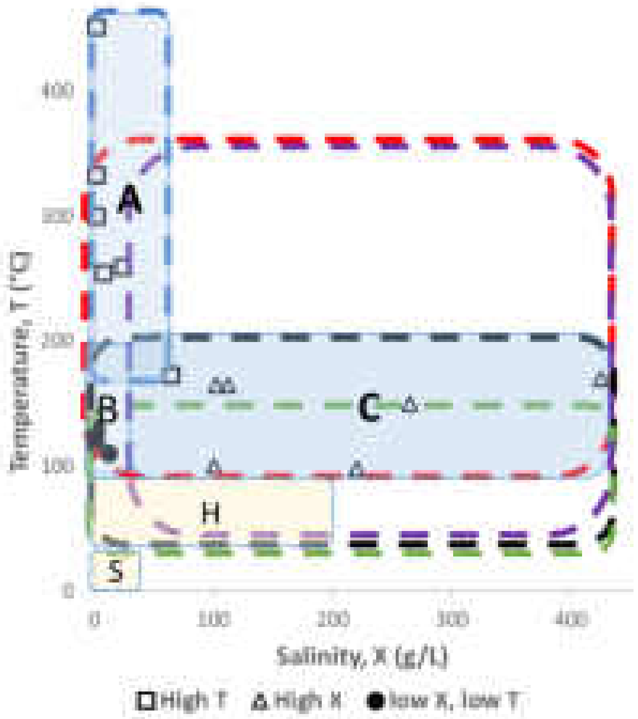
# Background: Properties of geothermal fluids




Dashed lines show knowledge gaps for fluid properties as addressed in REFLECT:

- blue: kinetics of silica polymerization and precipitation
- purple: data on mineral solubilities, Pitzer coefficients, fluid physical properties;
- red: degassing reactions
- Green: area of relevance for microorganisms
- black: occurrence of organics

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# Objective and concept


The efficiency of geothermal utilisation largely depends on the behaviour of fluids that transfer heat between the geosphere and the engineered components of a power plant.

Often encountered problems are **downtime, maintenance costs** and even **failure of geothermal installations** due to chemical and physical properties of the fluid resulting in:

- Mineral precipitation
- Degassing
- Corrosion

Examples of scaling: Top left: Silica Scale, Reykjanes, Iceland; bottom left: sulfide scale, Iceland (both © V.Hardardottir); top right: calicte scale Hungary (© Z.Istfan); bottom right: Fe, Mg scale (Tuzla, Turkey; © A. Baba)

Concept: From react to reflect!

The aim of REFLECT is to avoid the problems related to fluid chemistry rather than treat them.

Objective:

Accurate predictions by thorough knowledge of the physical & chemical properties of geothermal fluids

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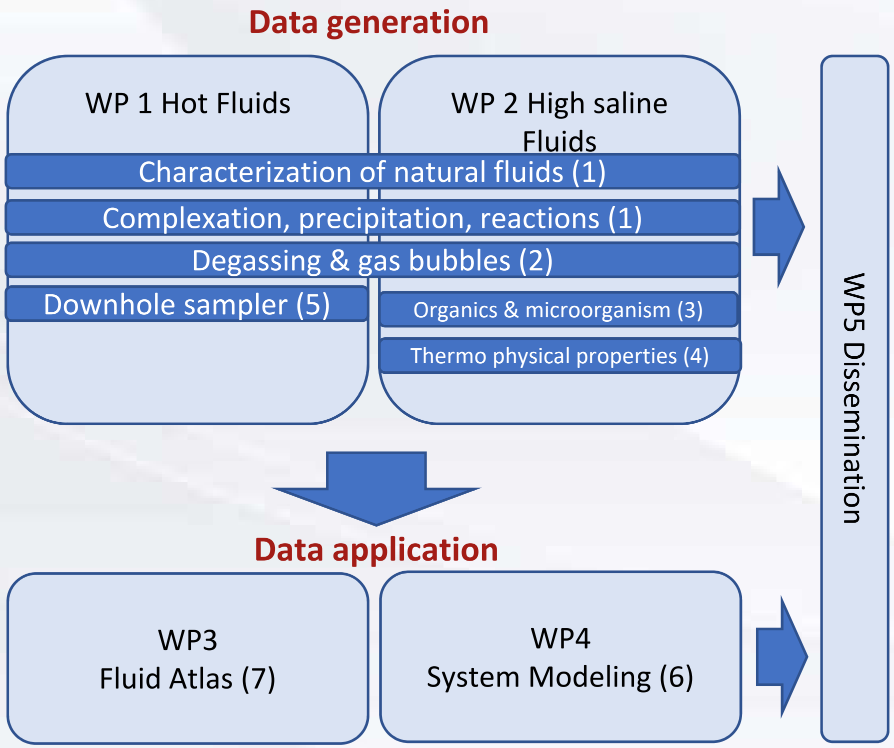
# Goals & structure

1. Extend databases for mineral precipitation to **higher temperatures** and **higher salinities** (field, lab, modelling)
2. Determine the extent and location of the **degasification** front of geothermal fluids
3. Determine types of **organic matter and microorganisms** in geothermal fluids
4. Determine fluid physical properties at various p, T, X
5. Develop a **downhole sampling** technique for hot and super-hot systems
6. Verification of the dataset by application in **reactive transport modelling**
7. Set up a **geothermal Fluid Atlas**

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# 1. Extend databases (solubility, activity, reaction kinetics) to higher temperatures and salinities

**Databases** on solubility, activity, reaction kinetics of various species: lab experiments and modelling approaches; focus on silica, calcite, stibnite

Monitoring mineral solubility by impedance spectroscopy

Monitoring mineral solubility by solution analysis

GFZ IFE brgm UK Research and Innovation

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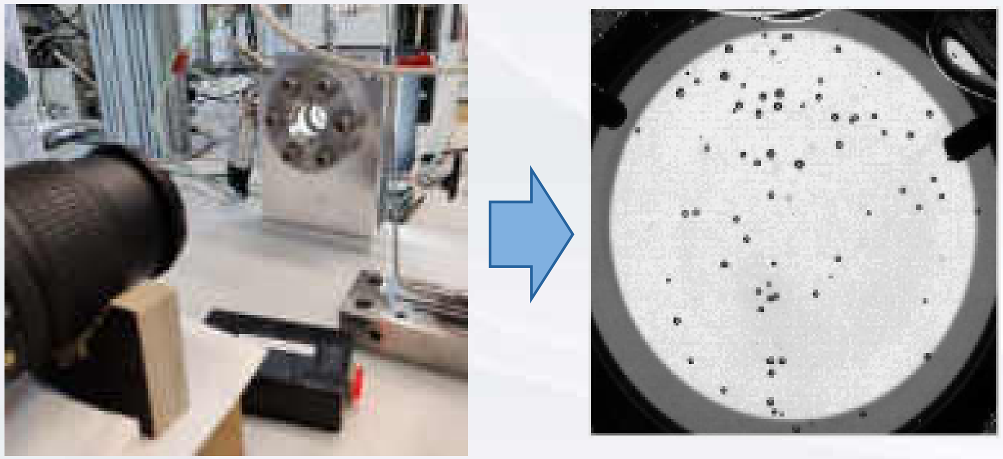
# 2. Determine the degasification front

## Extend and location of the degasification front of geothermal fluids during production (lab and modelling approach)

- → Degassing of $CO_2$ and $N_2$ saturated water has been studied using a visual cell and a high-speed camera at elevated pressures (up to 100 bar) and temperatures (up to 100 ° C).
- → Comparison of experimental results to numerical models
- → coreflood experiments in a CT-scanner to to characterise degassing in rock samples



Visual cell and high speed camera. Images with gas bubbles. .

TU Delft

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# 3. Types and Role of Organic matter and Microorganisms

**Determine types of organic matter and microorganisms in geothermal fluids and their effect on scaling and biofilm formation via laboratory studies**

- Review of existing information on organic matter and microorganisms in geothermal fluids
- Validate and apply methods for the measurement and identification of microorganisms and organic matter to samples collected
- Characterization of organic matter and microorganisms at REFLECT sites

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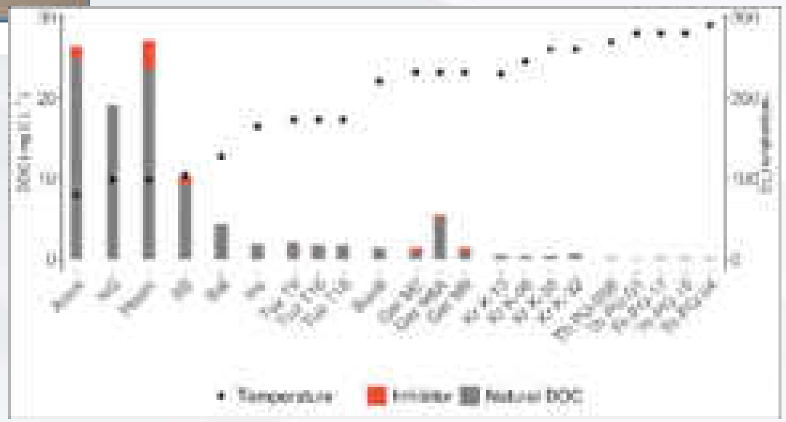
# 3. Types and Role of Organic matter and Microorganisms

- Various types of microorganisms at the investigated geothermal sites

- Correlation between T and DOC; differentiation to Inhibitors



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# 4. Fluidphysical properties

**Determine heat capacity, density, electrical and thermal conductivity, sonic velocity, and viscosity at various p, T, X (lab & modelling)**

- **Measurements (density, viscosity) are underway** to quantify the effect of minor constituents in saline fluids on these properties.
- Original **density data (GFZ) was compared to numerical predictions** (BRGM) yielding an excellent match.
- **Electrical conductivities of carbonate** solutions at different concentrations are measured up to 450° C to determine limiting conductivities and association constants
- **Numerically, a new thermodynamic model for the H-Li-Na-K-Ca-Mg-Cl-H2O chemical system** has been developed, from dilute solutions up to salt saturation, and for temperatures up to 250° C

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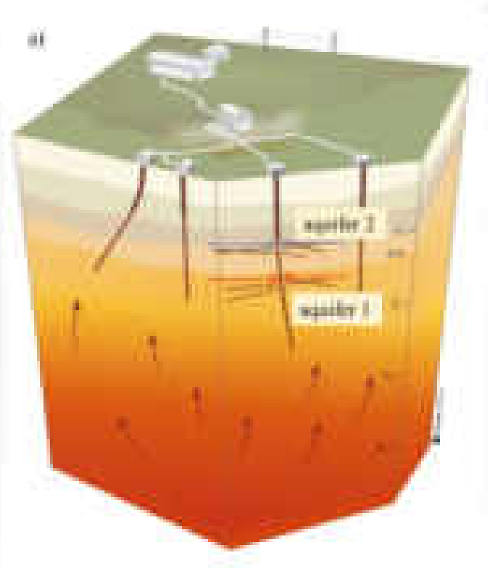
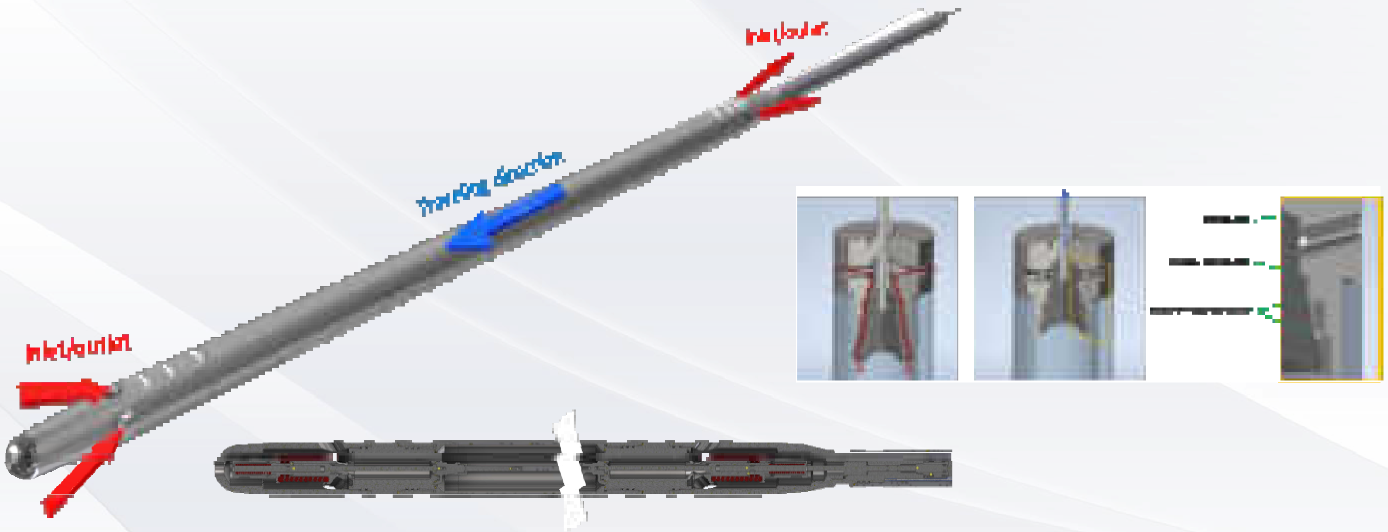
# 5. Downhole sampler for high-temperature geothermal wells





*REFLECT downhole sampler that has been developed to be able to sample various phases (liquid, two-phase, steam) at low to high temperature/high pressure superheated/supercritical conditions in geothermal wells. (© ÍSOR)*

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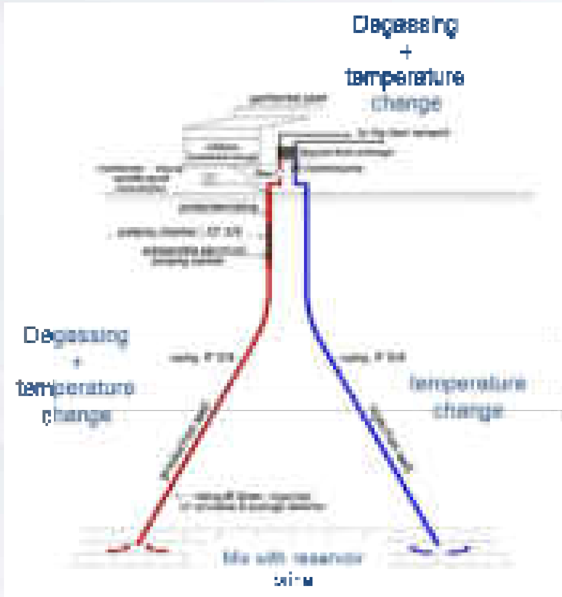
# 6. Implement the new dataset into predictive modeling

## Verification and implementation of the improved dataset by application in reactive transport modelling

→ open-source, generic, multi-scale package porousMedia4Foam
Deliverable 4.1 provides the User's guide for the software

→ workflow for uncertainty quantification in the fluid composition and its impact on scaling

→ Release of the numerical tool coupling transport and chemical reactivity




From Kervevan et al., 2014

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# Goals 1 & 7: Natural fluids and Fluid Atlas

## Extend databases for fluids and develop a digital fluid atlas for Europe

**All partners**


**Approach:** Collect information on properties of geothermal fluids throughout Europe

- data include geographical, geological, physical, chemical, and microbial properties

**Purpose:** give information needed for the planning and managing of geothermal facilities and thus to facilitate future geothermal projects.

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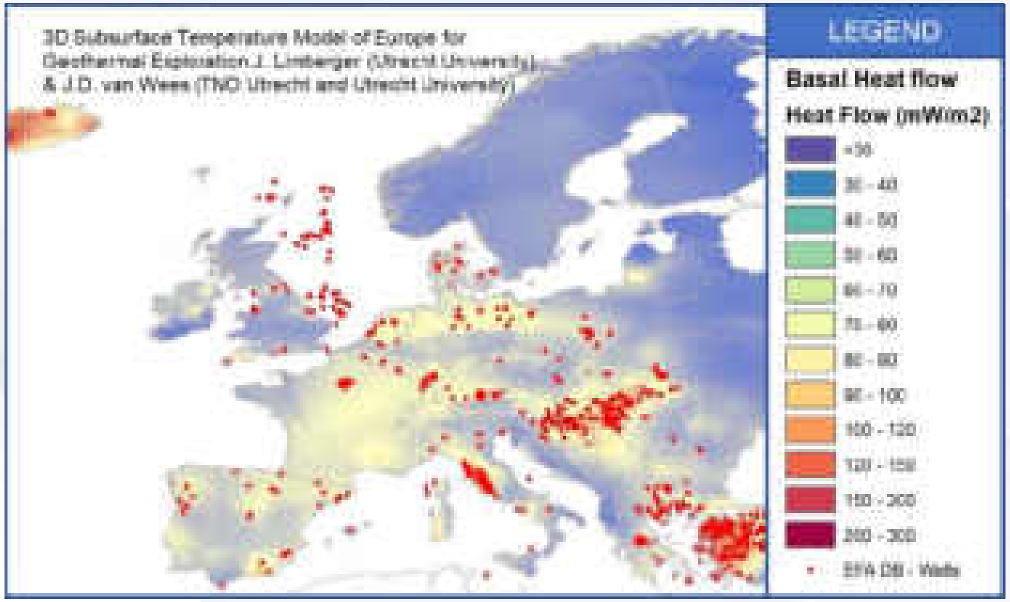
# 7. European Geothermal Fluid Atlas

## Set up a geothermal Fluid Atlas that collates information on geothermal fluid properties (existing data and new data) across Europe together with their geological setting

https://www.reflect-h2020.eu/efa/

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# Thanks to the Team

*Three years ago:*
*Kick-off meeting, Potsdam (2020)*

*Many zoom meetings*

*Izimr, General Assembly (June, 2022)*

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# Raw materials from geothermal fluids: occurrence, enrichment, exploitation

https://crm-geothermal.eu/

Simona Regenspurg, Katrin Kieling

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101058163.

# Background idea

**Traditional mining**

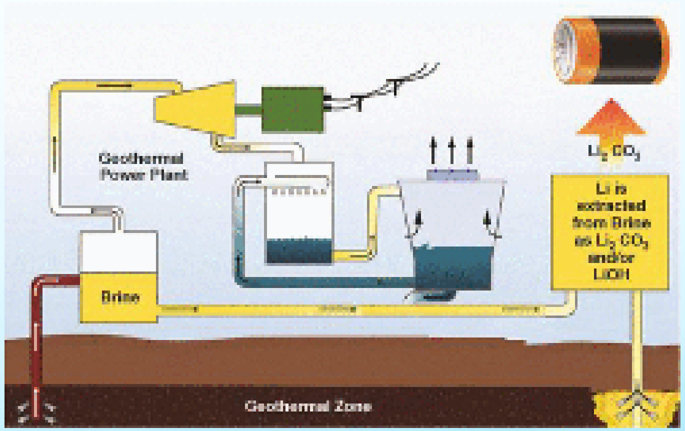
- High energy consumption during mineral extraction and processing
- Strong negative environmental impact
- High dependence on other countries

*Lithium valley © Tagesspiegel.de*

**Mining at  geothermal settings**

Geothermal fluids and settings are often loaded with several valuable elements

→ (Critical/strategic/valuable) raw materials could be extracted from brine/gas before reinjecting the fluid in the geothermal reservoir or from the scaling.




*Lithium extraction geothermal brine (Paranthaman, et al., 2017)*

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# Critical Raw Materials

CRM:  economic importance for the European industry and its supply risk

| 2020 critical raw materials (new as compared to 2017 in bold) | | |
|---|---|---|
| Antimony | Hafnium | Phosphorus |
| Baryte | Heavy Rare Earth Elements | Scandium |
| Beryllium | Light Rare Earth Elements | Silicon metal |
| Bismuth | Indium | Tantalum |
| Borate | Magnesium | Tungsten |
| Cobalt | Natural graphite | Vanadium |
| Coking coal | Natural rubber | **Bauxite** |
| Fluorspar | Niobium | **Lithium** |
| Gallium | Platinum Group Metals | **Titanium** |
| Germanium | Phosphate rock | **Strontium** |

gas

brine

scale

*Quelle: https://ec.europa.eu/growth/sectors/raw-materials/specific-interest/critical_en*

**Others (strategic or vauble)**

He    Cu    Au

*Geothermal fluid: liquid and gas*

*Scaling (mainly native Cu)*

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# Example: Economic relevant elements at the geothermal research site Groß Schönebeck

| | | |
|---|---|---|
| Sb: nm | Hf: nm | P: nm |
| | In: < NG | Sc: 0.03 mg/L |
| Be: 1.9*E-3 mg/L | HREE: 0.00055 mg/L | |
| Bi: 1 mg/L | Light REE: 0.058 mg/L | Ta: nm |
| B: 95 mg/L | Mg: 180 mg/L | W: 0.09 |
| Co: 0.007 mg/L | | V: nm |
| | | |
| | Nb: nm | Li: 200 mg/L |
| Ga: 0.6 mg/L | Pt, Pa: nm | Ti: 0.02 mg/L |
| Ge: 0.01 | | Sr: 1400 |

| | | |
|---|---|---|
| Cu: 100 mg/L | Mn: 200 mg/L | Zn: 75 mg/L |

| | |
|---|---|
| $CH_4$: 13 vol % | $H_2$: 1 vol % |

*Groß Schönebeck; Norddeutsches Becken*

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# Reserach Questions

1. **Which** valuble elements in which concentrations occur in different types of geothermal settings (brine, gas, scale)?

→ overview and economic evaluation

2. **What** are the geological and geochemical processes & parameters responsible for an enrichment of these elements in the brine?

→ relevant for understanding / important for predicting)

3. **How** can the elements be extracted from brine, gas and scale during geothermal plant operation?

→ technology development and economic evaluation)

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# Project numbers

- **4** year project duration (start May 2022)
- **20** partners

| Participant No. * | Participant organisation name | Country |
|---|---|---|
| 1 (Coordinator) | German research centre for Geosciences (GFZ) | Germany |
| 2 | University of Miskolc (UNIM) | Hungary |
| 3 | International Raw Materials Observatory (INTRAW) | Belgium |
| 4 | La Palma Research Centre S.L. (LPRC) | Spain |
| 5 | Jacobs University Bremen (JUB) | Germany |
| 6 | United Kingdom Research and Innovation (UKRI) | UK |
| 7 | University of Neuchatel (UNINE) | Switzerland |
| 8 | University of Padua (UNIPD) | Italy |
| 9 | Dr. Brill Institute (BI) | Germany |
| 10 | University of Iceland (UoI) | Iceland |
| 11 | Cornish Lithium (CL) | UK |
| 12 | Geothermal Engineering Ltd (GEL) | UK |
| 13 | Izmir Institute of Technology (IZTECH) | Turkey |
| 14 | European federation of geologists (EFG) | Belgium |
| 15 | Flemish Institute for Technological research (VITO) | Belgium |
| 16 | University of Nairobi (UoN) | Kenya |
| 17 | INLECOM Innovation Astiki Mi Kerdoskopiki Etaireia | Greece |
| 18 | Hydroisotop GmbH (HI) | Germany |
| 19 | Levin Sources (LS) | UK |
| 20 | Natürlich Insheim (NI) | Germany |

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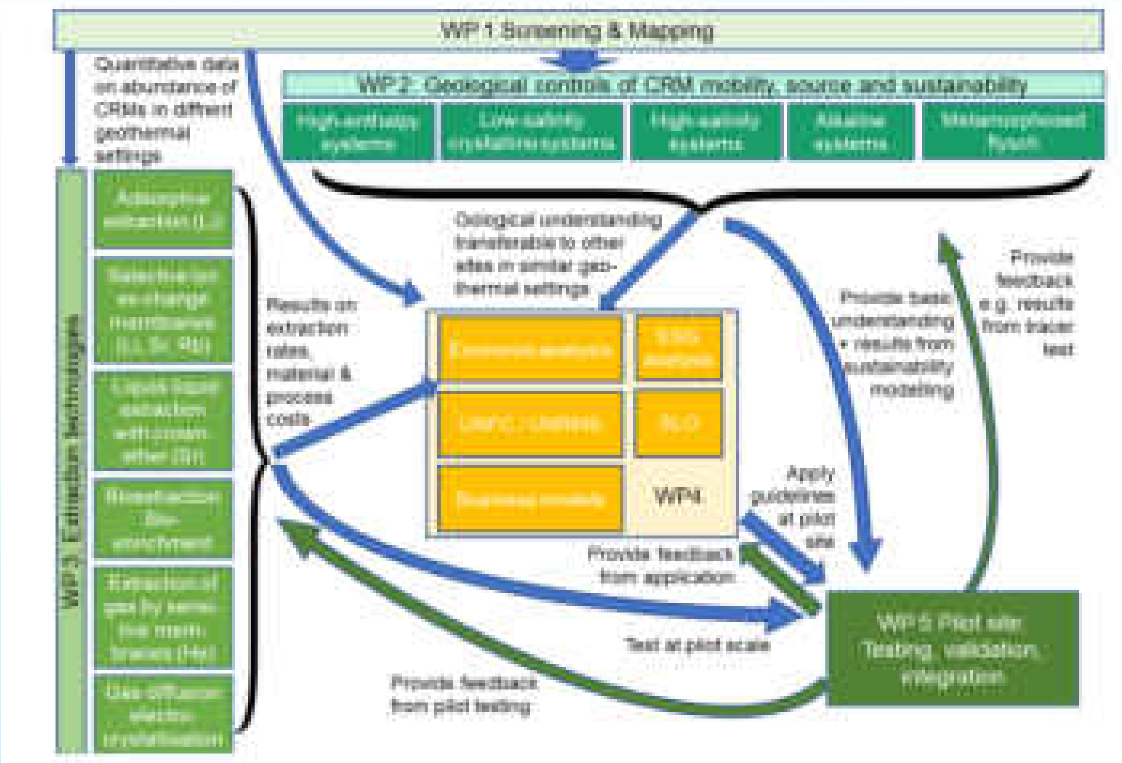
# Project Structure

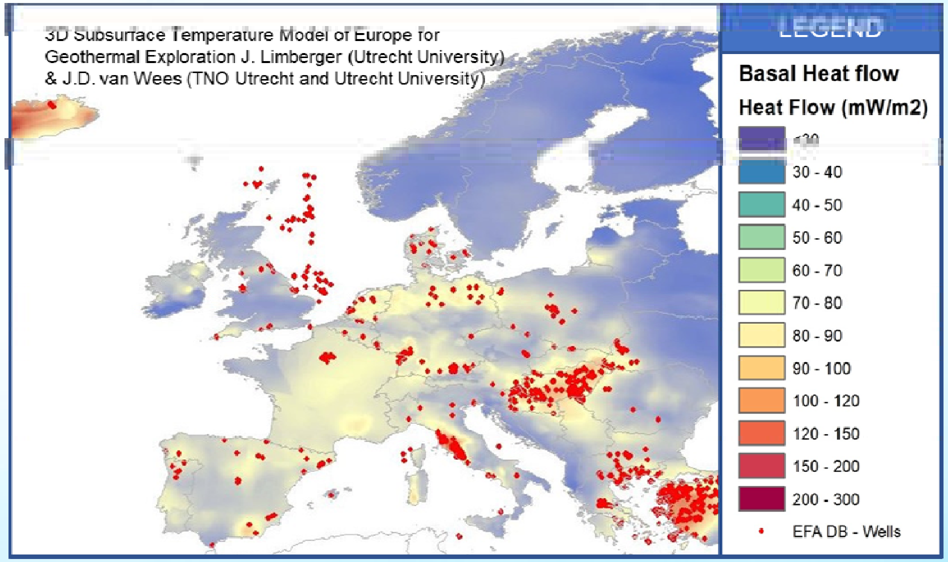



CRM geothermal

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101058163.

# WP1 – Screening and mapping of CRM-content in geothermal settings

- **Data collection and database creation**
- **Sampling and analysis of liquid, gas, and solids**
- **Data compilation**
- **Establishing CRM-geothermal Fluid Atlas for Europe and East Africa**
- **AI-based Simulation Tool** (predictive and prescriptive analysis of the data using artificial intelligence/machinge learning tools)




Current stauts of the REFLECT fluid atlas. Location of the 2400 wells where formerly existing well, fluid, rock and reservoir data have been collected. (Source: Karoly Kovacs, UNIM)

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# WP 2 Geological controls of CRM mobility, source and sustainability

- obtain better knowledge of the geological and geochemical controls of CRM enrichment in geothermal environments.
- quantify the long-term sustainability of extraction of CRM.
- obtain better knowledge of the enrichment processes of CRM in scales from high enthalpy settings (Iceland and Turkey).
- obtain better knowledge of the enrichment processes and sustainability CRM extraction from low salinity, crystalline rocks (Cornwall, German sedimentary basin).
- quantify REE + Y enrichment in alkaline geothermal areas (brine or scale) and track their source.
- demonstrate potential economic sustainability of CRM extraction at the study sites before the brines become depleted.

CRM geothermal

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# WP 2 Geological controls of CRM mobility, source and sustainability

- High enthalpy volcanic systems (Iceland, Turkey) → enrichment in scales
- Low salinity crystalline systems (Cornwall) → Li, Sr extrcation, leaching experiments, Miniplant
- Saline water in sedimentary basins (North German Basin and/or URG) → Li, Sr, Cu
- Alcaline systems (East African Rift) → Rare earth elements and helium in fluids, rocks and scales
- Metamorphosed flysch (Turkey) → Li, Sr…

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# WP3 – Development and optimisation of extraction technologies for CRM from geothermal brines

- Adsorptive extraction by ion sieves (GFZ, IZTECH)
- Selective Ion exchange membranes (Uni Padua)
- Adsorption by means of modified (bio-) polymers with crown ethers (GFZ)
- Bioextraction and bioaccumulation (Uni Neuchatel)
- He-extraction by membrane technology (GFZ)
- Gas diffusion electro-crystallisation (VITO)

Mini-pilot system at Tuzla site: Adsorption test for Li using Polyester fibers on which adhesive epoxy resin with the adsorbent is applied. (Source: Mustafa M. Demir, IZTECH)

CRM geothermal

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