Karlsruhe Institute of Technology

Federal Ministry for Economic Affairs and Climate Action

Smart Energy Systems ERA-Net

GEOTHERMICA

MALEG

Machine Learning for Enhancing Geothermal Energy

MALEG – Machine Learning for Enhancing Geothermal Energy

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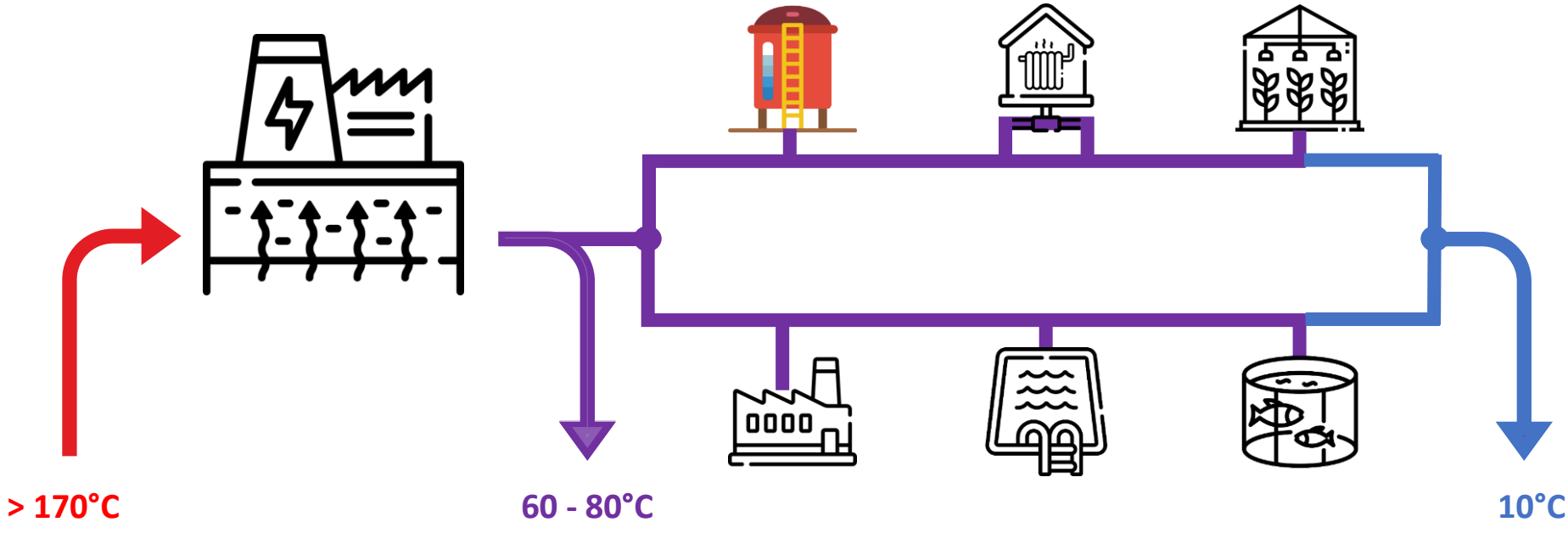
Challenge and Project Concept

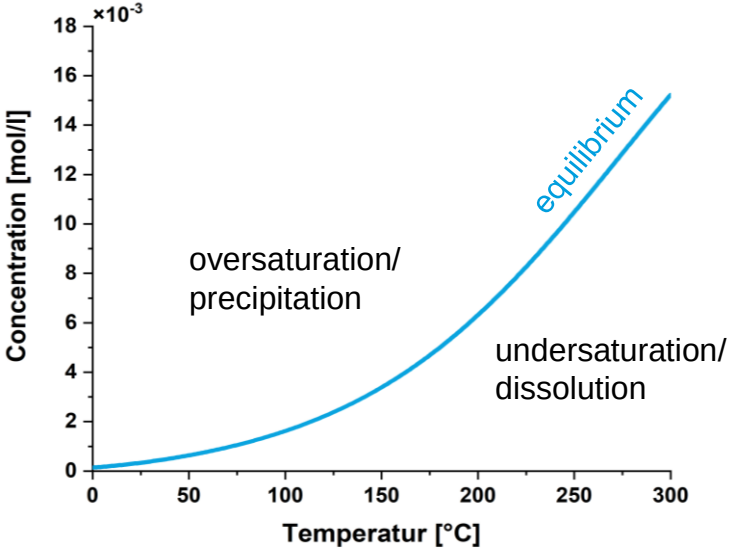
- Increase of energy output from deep geothermal production
  - Stretching ΔT by lowering reinjection temperature

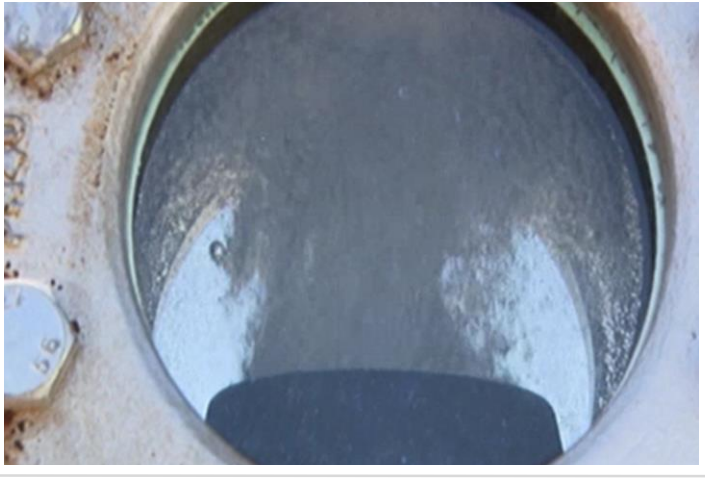


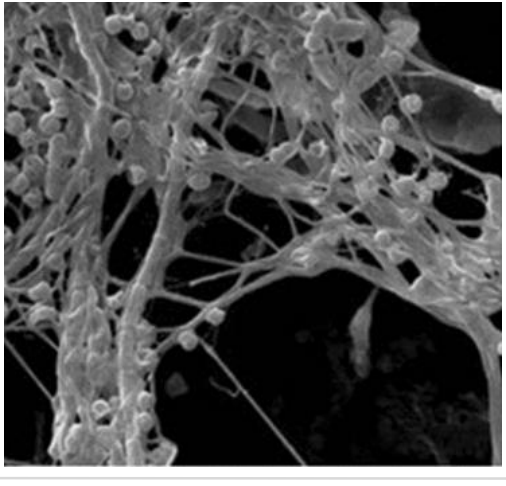
Challenge and Project Concept

Hydro(-bio)chemical Constraints

- Higher perturbation of the chemical system with increasing ΔT, Δp, Δx,…
- Larger potentials for
  - Mineral precipitation (scaling)
  - Degassing
  - Biofilm formation

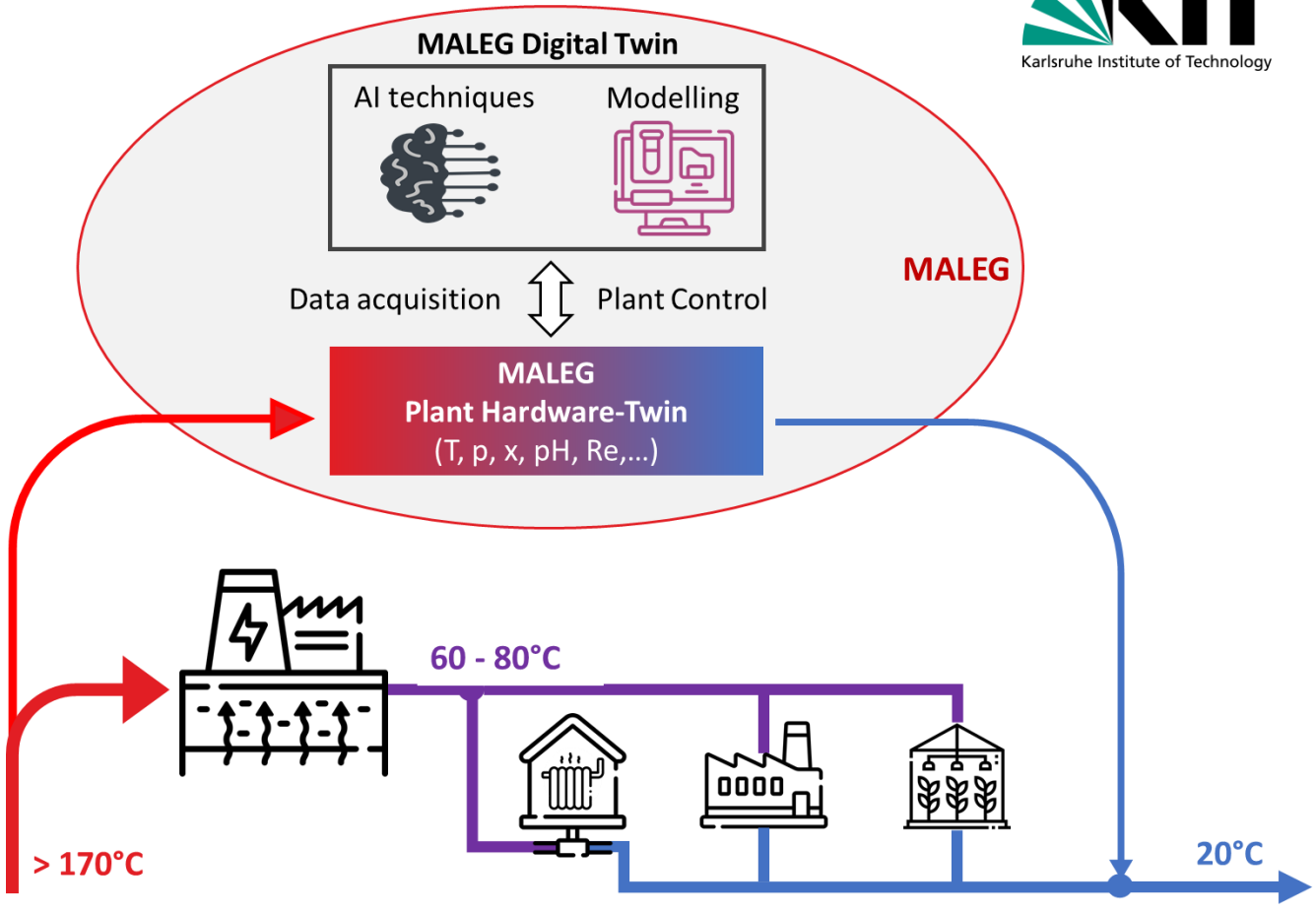






Project Approach

- High density hydrochemical data acquisition over large parameter range
  - T, p, x, pH, q, Re,…
- Training of AI and adaption of thermodynamic data
  - Scaling, degassing, biofilm
- Implementation of AI- and modelling-based digital Twin
  - Constrain the chemical system



Project & Partner

- Joint ERA-net & GEOTHERMICA project
  - Funded through BMWK
- Total project volume
  - 1.8 mio €
  - 2022 - 2025

Project Locations

Unterschleißheim, Germany

Ein Unternehmen der Stadt Unterschleißheim

Geothermie Unterschleißheim AG

FERNWÄRME HAAG GEOTHERMIE

Haag am Hausruck, Austria

Transmark Renewables

Gülpinar, Turkey

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MALEG Hardware-Twin

- Hardware-Twin was constructed and tested at the Fraunhofer ISE
- Installed at the geothermal heating plant in Haag (A)
  - Coupled to the plant directly
  - In continuous operation since three month
- First monitoring/experiments are underway
  - Bio-film growth
  - Impact of temperature/flow rate due to seasonal demands changes

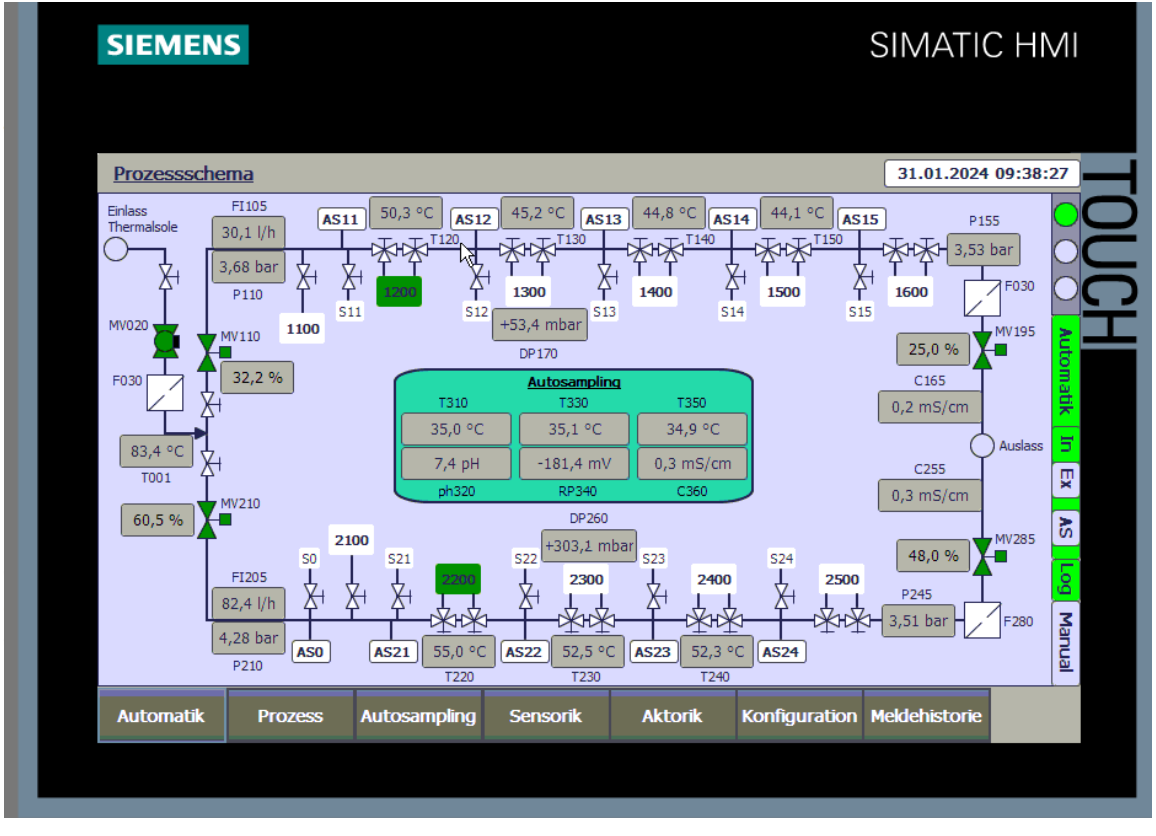
MALEG Hardware-Twin
Features

- Control of operation parameters
  - Flow rate
  - Temperature
  - Pressure
  - Residence time
  - Fluid velocity
  - Dosage of chemicals
- Measurements and quantifications
  - Temperature, pressure, flow
  - pH, Redox

  → Mineral precipitation

  → Bubbling point

  → Bio-film



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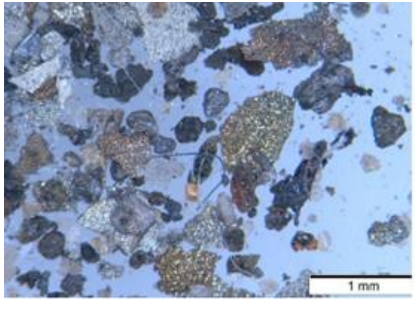
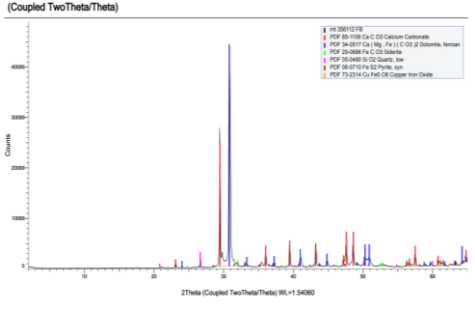
Monitoring
Sampling and Analytics

- Monitoring of the chemical systems at the project locations at normal operations
- Sampling and analysis of fluids, gases and solids in the experimental phases
  - Identification
  - Quantification
- Creation of “large” datasets
- Identification and continuous measurements of “proxy” parameters

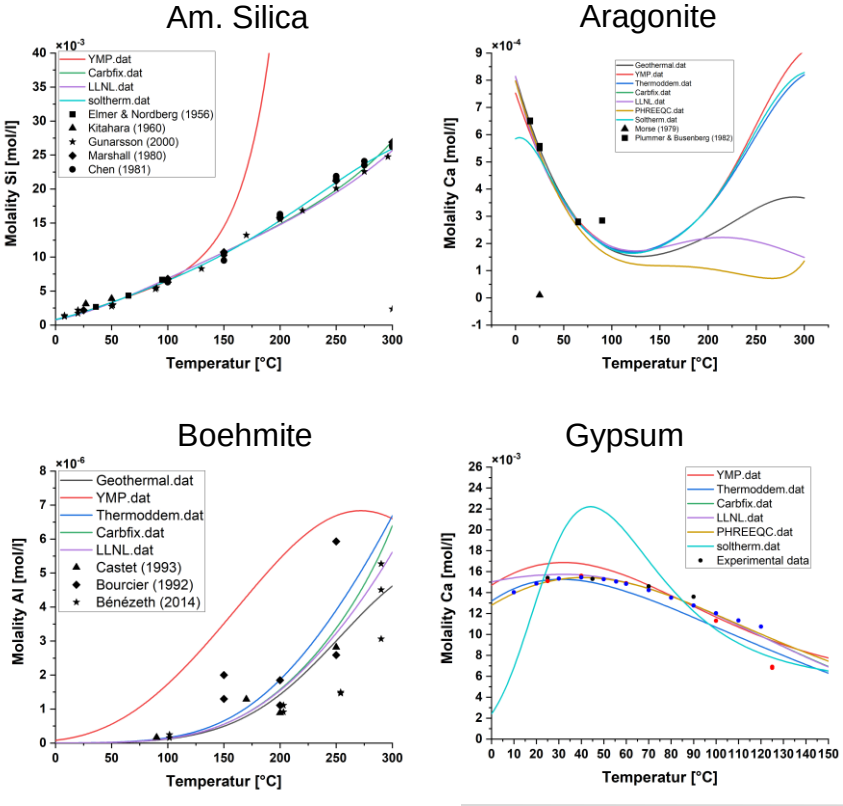




MALEG Digital-Twin

Thermodynamic modelling of mineral saturation/scaling

- Goal: Improvement of thermodynamic scaling prediction modelling in geothermal environments
- Validation of thermodynamic data sets for scaling minerals versus lab data
- Compilation of a valid “scaling minerals” thermodynamic database
  - Compatible with PhreeqC



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MALEG Digital-Twin

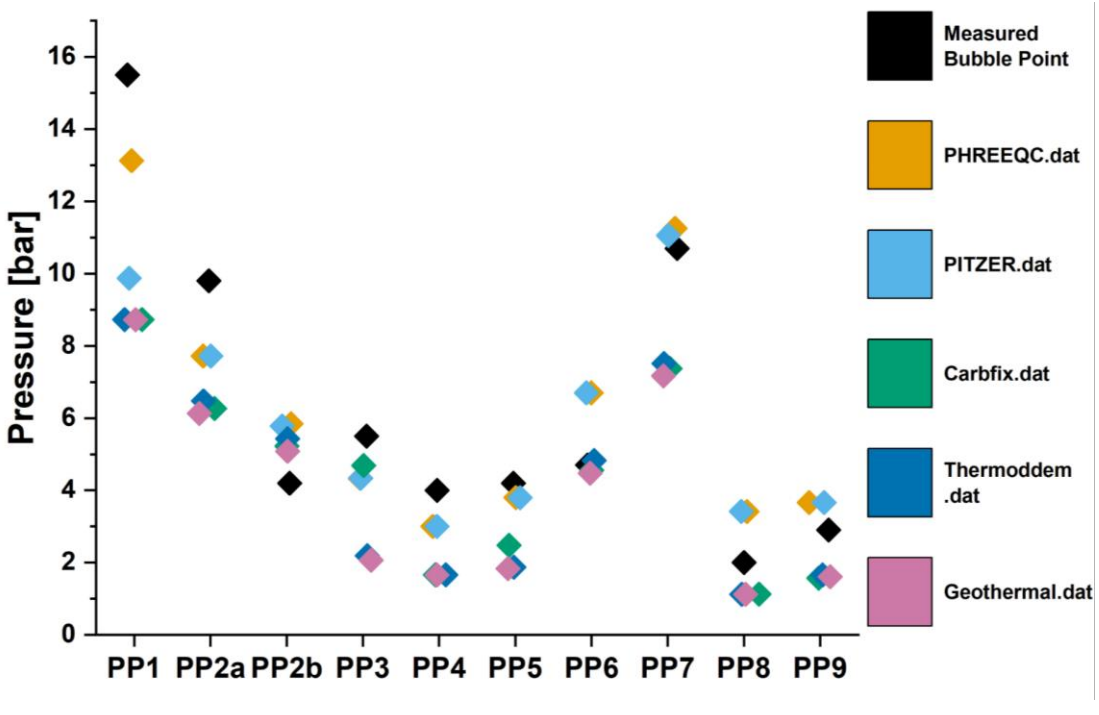
Thermodynamic modelling of bubbling point

- Assessment of modelling performance for the determination of the bubbling point
- Testing of existing thermodynamic data sets versus onsite measurements

→ Highly deviating results

→ Non-systematic offsets

→ Strongly site-dependent



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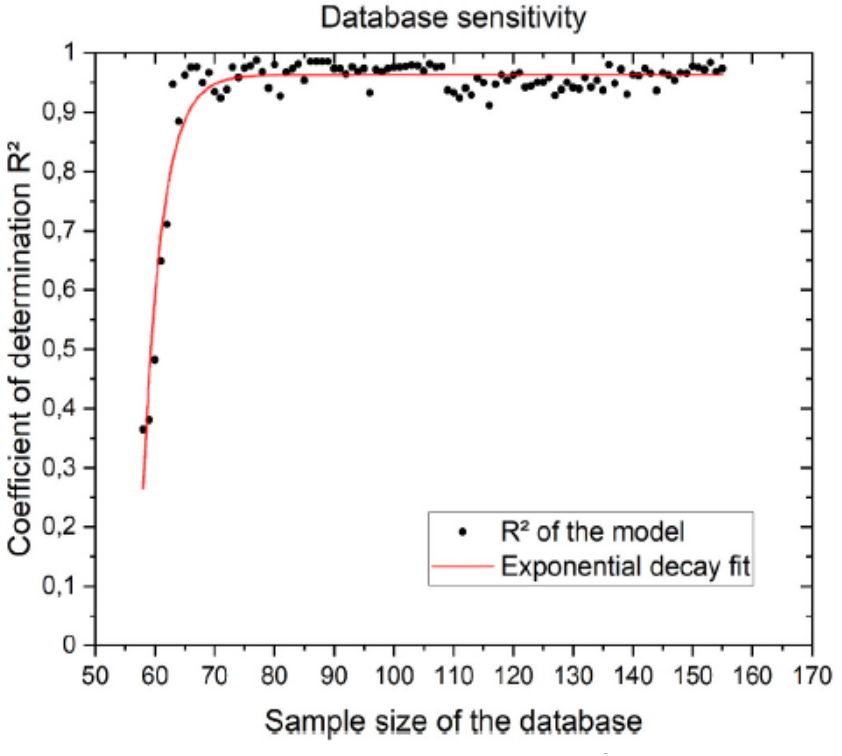
MALEG Digital-Twin

Advanced Statistics and Machine Learning

- Are machine learning methods applicable to hydrochemical datasets?
- Challenges
  - Small data size
  - Very large number of parameters (e.g. chemical elements)
  - Large variation of concentration (over many orders of magnitudes)
  - Unfavourable concentration distributions
  - …
- **Yet very good first results**



Conclusions

- MALEG Hardware-Twin constructed, tested and in continuous onsite operation in Haag am Hausruck
- First experiments are conducted and ongoing
- New thermodynamic data base for scaling minerals under geothermal conditions compiled and validated
- Application of AI methods on hydrochemical data sets tested and adapted yielding promising very results

Next steps

- Large scale data acquisition experiments
- Training of hydrochemical AI

The Team

Thank you for your kind attention