Accelerating CCS Technologies

Synergetic Utilisation of CO_2 storage Coupled with geothermal EnErgy Deployment – SUCCEED

"ACT – Accelerating CCS Technologies" Project No: 294766

01 September 2019 – 31 August 2022

ZORLUENERJi

OR Reykjavík Energy

Imperial College London

Middle East Technical University

TU Delft

OGS

SILIXA

seismic mechatronics

Geothermal Energy and CO_2 Emissions

- The non-condensable gases in deep geothermal resources include CO_2 and smaller amounts of ammonia, nitrogen, methane, hydrogen sulphide, and hydrogen.
- CO_2 concentration in the non-condensable gases can be as high as 97.8% and, together, the non-condensable gases typically make up around 4-5% by weight.
- In some countries, geothermal energy production contributes significantly to their energy budget, and the CO_2 emissions from geothermal power plants are relatively significant. For example:
  - In Turkey, the 1,174 MWe installed geothermal capacity may be emitting over 4M tonnes CO_2 to the atmosphere each year.
  - In Iceland, the current installed capacity of 665MWe could emit as much as 550,000 tonnes of CO_2 each year.
  - In Italy, the 916 MWe installed geothermal capacity could be emitting over 2.5M tonnes per annum of CO_2

Role of CO_2 in Geothermal Productivity

On the other hand,

- CO_2 is a valuable feature of the geothermal resource as it improves productivity.
- The produced fluid, depleted in CO_2, is generally re-injected into the reservoir. As a consequence, the geothermal fluid resource in the reservoir is gradually diluted and the field pressure is reduced over time, affecting well productivity.
- Such degassing effect of geothermal production at the Hellisheidi field in Iceland reported a reduction of mass flow of CO_2 from 120 tonnes/day to 100 tonnes/day since early 2014.

Objectives of SUCCEED

An industrial CO_2 storage project which, besides its focus on "CO_2 storage and utilisation", also aims to develop, test and demonstrate, at field scale, innovative measurement, monitoring and verification (MMV) technologies that can be used in most CO_2 storage projects. The objectives of SUCCEED are:

- to research and demonstrate the feasibility of utilising produced CO_2 for re-injection into a carbonate reservoir to maintain reservoir pressure and improve geothermal performance while also storing the CO_2
- to test and demonstrate innovative monitoring technologies applicable in all CO_2 storage field sites:
  - the new higher signal-to-noise ratio Distributed fibre-optic Acoustic Sensing systems iDAS and Carina®
  - the new permanent and highly repeatable vibratory-type (environmentally friendly) seismic monitoring EM-vibrators, and

  to provide semi-continuous seismic monitoring capability at **HPHT** environments,
- to investigate rock-fluid interactions under simulated **HPHT** conditions in the laboratory and determine geochemical, geomechanical and geophysical response of the reservoir rocks to supercritical CO_2,
- to model and investigate injected CO_2 as well as reservoir rock behaviour in the long-term,
- to develop strategies for pressure management in geothermal reservoirs through supercritical CO_2 injection at the Kizildere field site.
- To develop reliable technoeconomic and life cycle environmental impact assessment methodologies for CO_2 storage in geothermal projects and implement these models to evaluate the geothermal resource in the Büyük Mendres Graben.

Project Partners

- Imperial College London (Project Coordinator, UK)
- Silixa Ltd (UK)
- Zorlu Enerji Elektrik Üretim A.S. (Turkey) Field site and wells
- Delft University of Technology (the Netherlands)
- Seismic Mechatronics BV (the Netherlands)
- Middle East Technical University (Turkey)
- Orkuveita Reykjavíkur/Reykjavik Energy (Iceland) Field site and wells
- Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (Italy)

The institutes/industry shownin red are from Non-ACT countries participariong with their own funds

Two Geothermal Field Sites

Kızıldere site operated by Zorlu Energy:

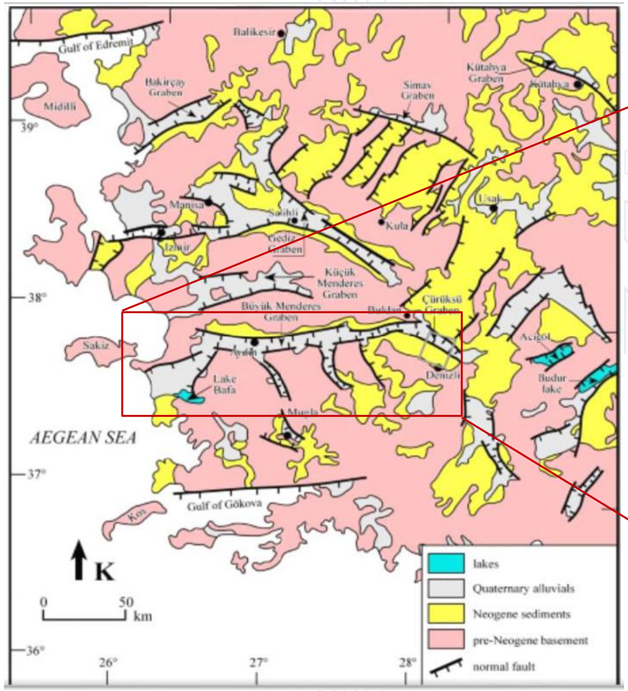
- 260 MWe installed capacity
- 2,000 – 3,500 m reservoir depth
- 220 – 245 ^{o}C reservoir temperature
- producing 7,500 tonnes/hr geothermal fluid and reinject 6,000 tonnes/hour of the spent fluid
- Supercritical CO_2 injection in a carbonate reservoir
- Aimed at reducing CO_2 emissions while enhancing geothermal performance and storing CO_2

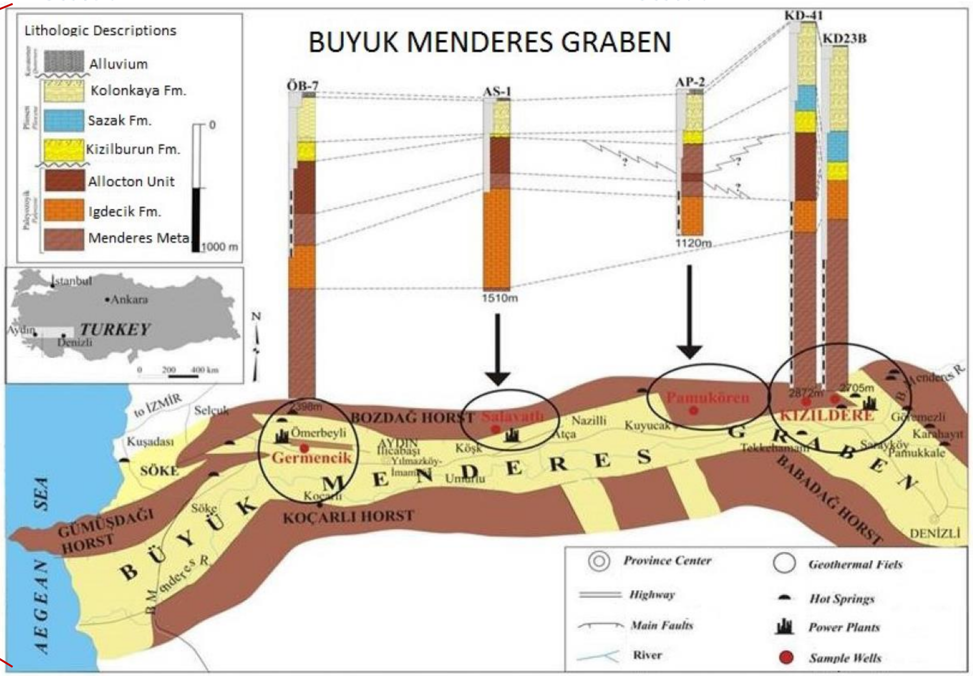
Hellisheidi site operated by Reykjavik Energy:

- 303 MWe installed capacity
- 700 – 2,500 m reservoir depth
- 270 – 300 ^{o}C reservoir temperature
- producing 4,500 tonnes/hr geothermal fluid and reinject 3,800 tonnes/hour of the spent fluid.
- Fractured basalt reservoir
- CarbFix2 project site re-injecting CO_2 dissolved in spent geothermal fluid since 2014. Latest CO_2 injection rate 10,000 tonnes per annum. Also has a seismic monitoring network (https://www.carbfix.com/)

Kızıldere Geothermal Field, Turkey

Location of Kızıldere geothermal field in Büyük Mendres Graben

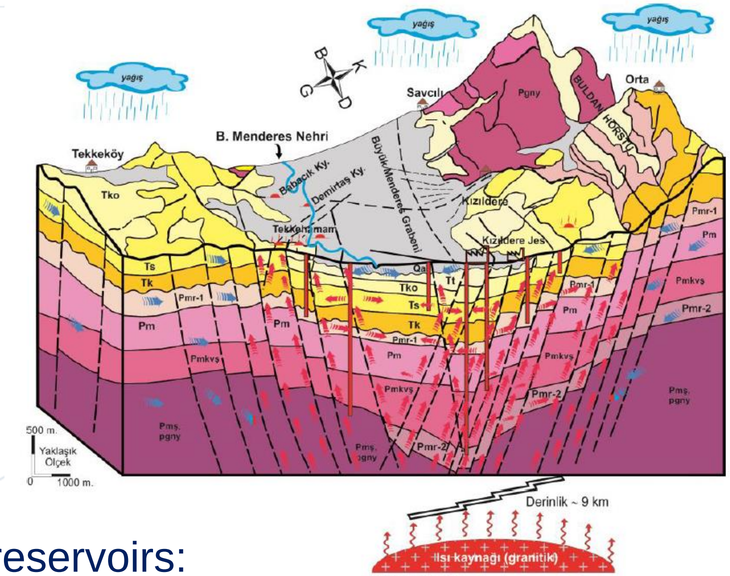




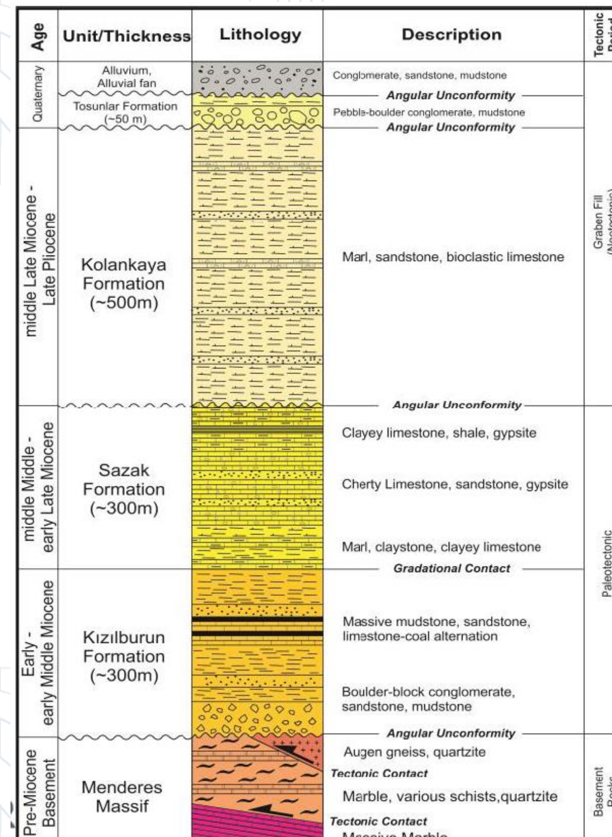
- Kızıldere geothermal field is located in the East of Büyük Menderes graben in Western Anatolia .
- The Büyük Menderes Graben is about 3–30 km wide, 170 km long. Approximately E–W-trending depression area.

Kızıldere Geothermal Field, Turkey

Conceptual geology of the Büyük Menderes Graben geothermal fields



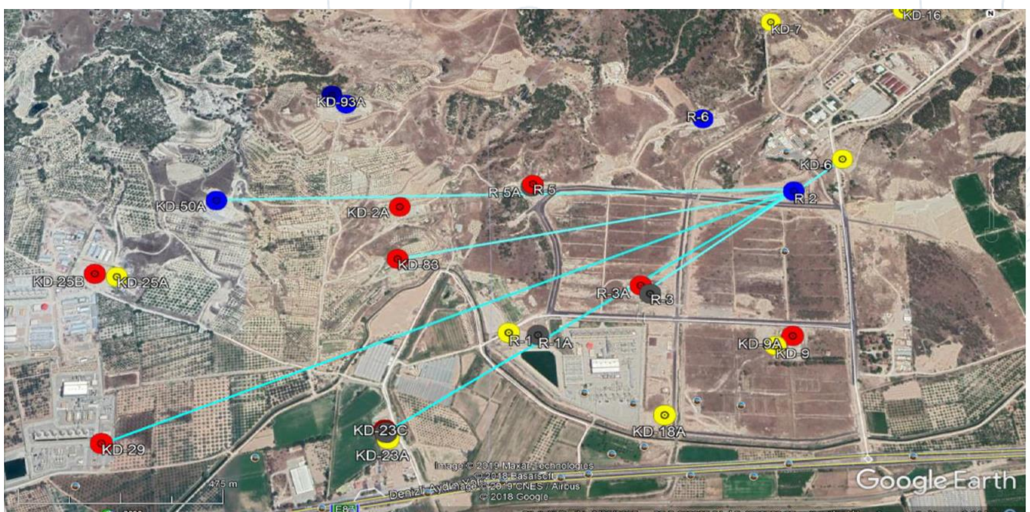
- Made up of three main reservoirs:
  - the upper reservoir within the Pliocene limestones of the Sazak Formation,
  - the intermediate reservoir within the Palaeozoic marble–quartzite–schist intercalations of the Iğdecik Formation, and
  - the deep reservoir hosted within the gneisses and quartzites that are intercalated with, and underlie, the schists
- The geothermal waters are of meteoric origin.



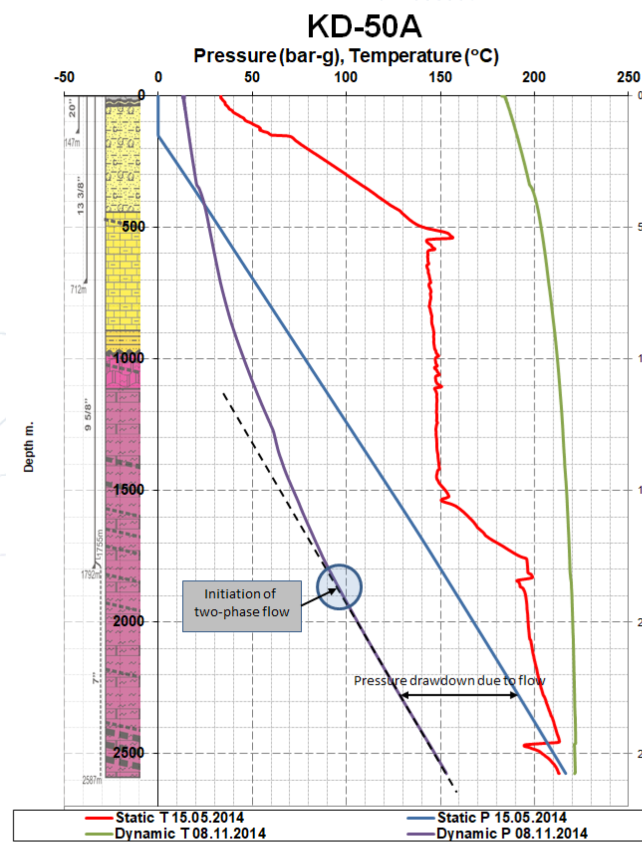
Kızıldere Geothermal Field, Turkey

Well fields and historical monitoring data

Tracer monitoring data



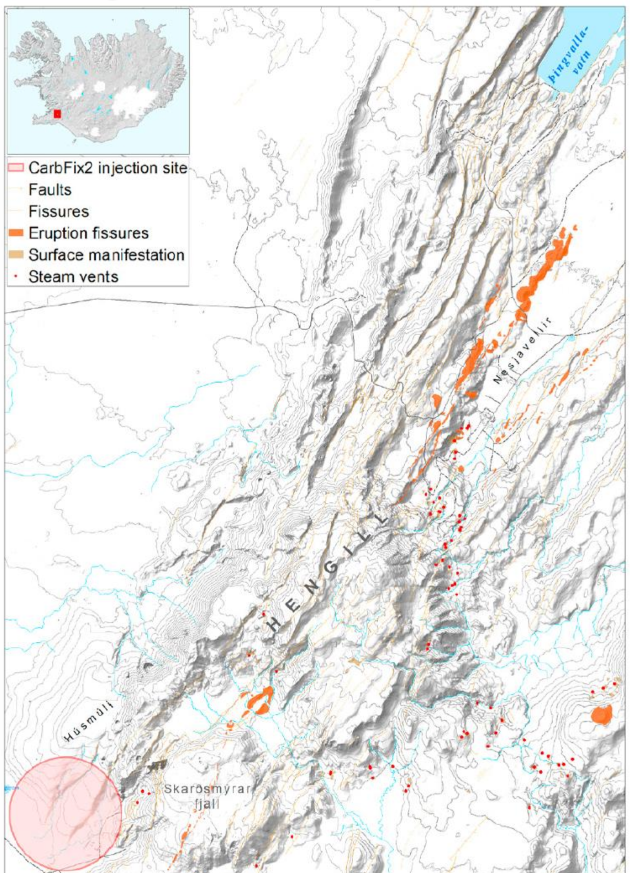
Production PT monitoring data

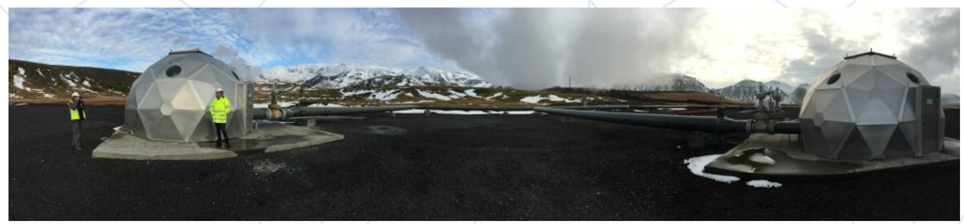


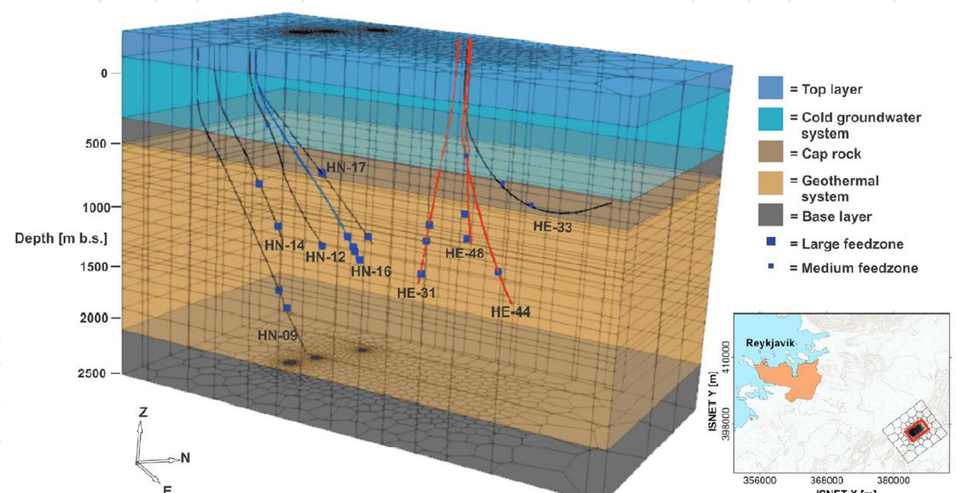
Hellisheidi Geothermal Field, Iceland

CarbFix2 CO_2 injection site

Hengil volcanic system

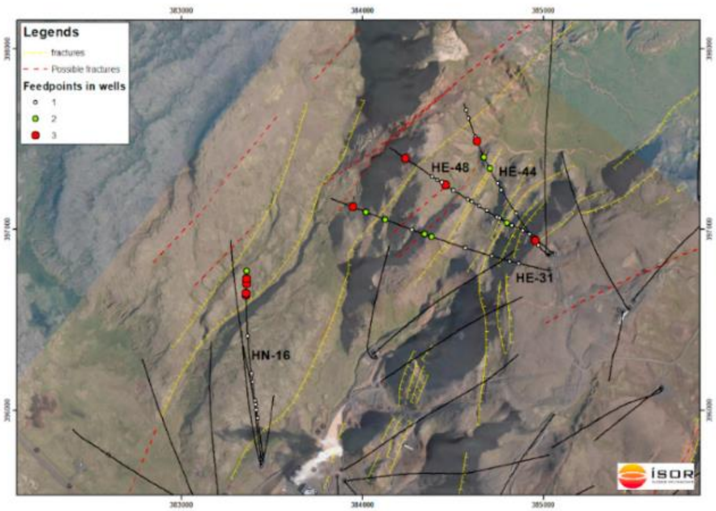




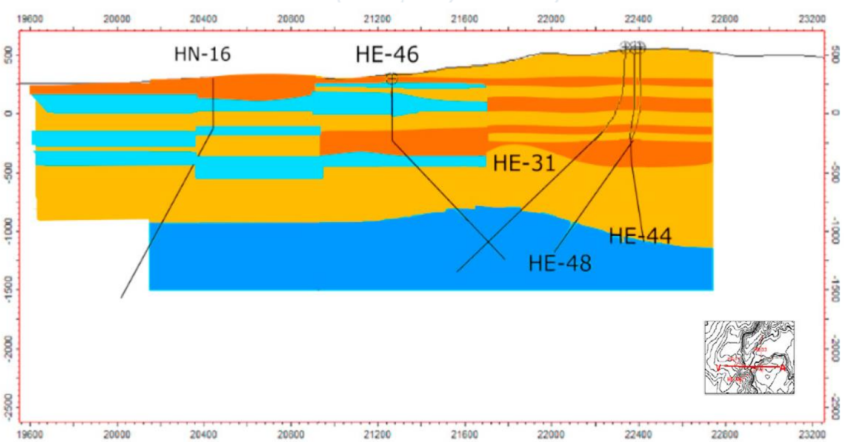


Hellisheidi Geothermal Field, Iceland

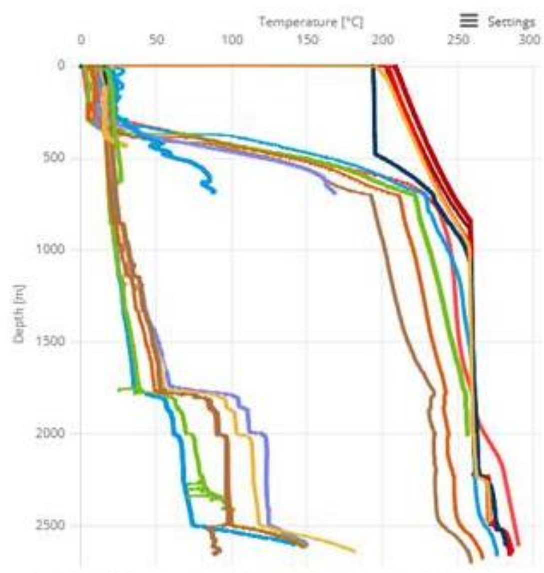
CarbFix2 CO_2 injection project



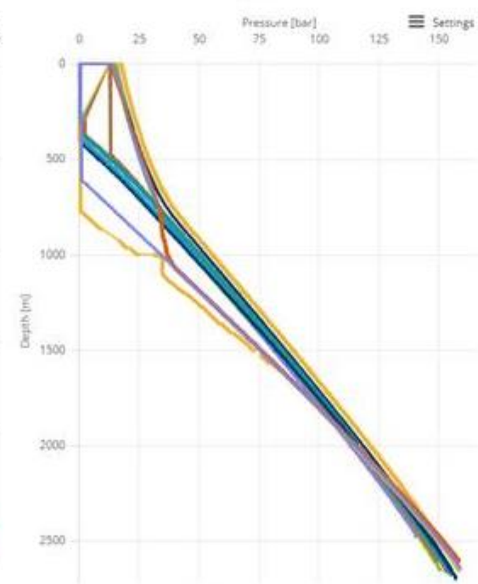
- CO_2 charged water and the spent geothermal fluid are injected to a depth of 750 m.
- It then is allowed to mix until it enters the main feed zones at 1,900 m and 2,200 m depth in the injection well HN-16
- Monitoring wells HE-31, HE-48 and HE-44 at distances 984, 1,356 and 1,482 m away from the injection well at reservoir depth.
- Historical geochemical and microseismic monitoring data



Temperature



Pressure



Project Tasks

- **WP1: Site and reservoir characterisation studies (METU)** Baseline site characterisation work at the Kizildere and Hellisheidi sites.
- **WP2: Planning and installing site infrastructure for supercritical CO_2 injection at Kizildere (ZORLU/OR)** Technical, operational and infrastructure requirements for safe and controlled CO_2 injection at Kizildere site.
- **WP3: Laboratory investigations into rock-fluid interactions: geochemical, geomechanical and geophysical response of the reservoir to supercritical CO_2 injection (TUD)** Determine the effects of injected CO_2 on the reservoir rock, and the mobility of the geothermal fluid in the wellbore region.
- **WP4: Field monitoring of CO_2 injection, site performance and reservoir behaviour (OGS)** Field testing of the vibratory-type EM sources developed and a new higher signal-to-noise ratio iDAS and Carina® systems under HPHT conditions at both Kizildere and Hellisheidi sites . The dataset of the local seismic network at Hellisheidi geothermal field will be utilised to assess the potential for injection induced seismicity.
- **WP5: Reservoir modelling of alternative injection and reservoir performance scenarios (IMPERIAL)** pre- and post-CO_2 injection simulations of the changes in reservoir pressure, associated geochemistry and geomechanical reservoir properties. This will mostly concern with the Kizildere site.
- **WP6: Techno-economic assessment and optimisation of a field-wide CO_2 injection strategy (IMPERIAL)** Learnings from WPs 1-5 and to identify strategies that optimise the performance of the CO_2 storage operations in geothermal fields and implement the models developed to evaluate the geothermal resource in the Büyük Mendres Graben.
- **WP7: Life cycle environmental impact and stakeholder/public communication, education and training (IMPERIAL)** To establish life cycle assessment (LCA) models that reflect the engineering processes in CO_2 storage operations.
- **WP8: Project coordination and management activities (IMPERIAL)**

Project Costs and Funding

- **Total Budget** :
  - €3,892,365 between 8 (Eight) partners

- **Budget breakdown** :
  - €2,533,939 funded by the ACT Consortium Countries
  - €1,358,425 by the Partner Institutions and Companies

- **Budget breakdown** :
  - €400,000 funded by the non-ACT Consortium Partners (OGS and OR) as own contribution

Acknowledgements

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