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ENOS
ENABLING ONSHORE CO_2 GEOLOGICAL STORAGE IN EUROPE

The Newsletter

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ENOS

Content

Seasonal CO_2 storage in Q16-Maas, ENOS field site in The Netherlands

Greenhouses benefit from elevated temperatures and CO_2 levels for optimal crop growth. Conventionally, heat and CO_2 are obtained by combustion of natural gas in combined heat and power (CHP) installations. To increase sustainability, geothermal heat is being introduced in the greenhouse sector, which is only an attractive option if an affordable and secure source of CO_2 is available. In the Westland area of The Netherlands (Figure 1), part of the greenhouse sector currently uses waste CO_2 from two sources in the port area near Rotterdam, which would otherwise be emitted. The CO_2 is transported by the OCAP pipeline from the Maasvlakte, delivering approximately 500 kt CO_2 on a yearly basis, with abundant opportunities for growth by connecting more greenhouses. At present, there is a mismatch between CO_2 supply and demand with a surplus in winter and shortage in summer. In addition, with only two sources connected to the OCAP distribution system, interruptions of CO_2 supply at either cause high costs for the greenhouses, which then have to accept less production, burn natural gas to produce their own CO_2 (in most cases), or have CO_2 delivered by truck.
Seasonal buffering in a geological formation, injecting excess CO_2 in winter and back-producing in summer, would:
- support growth in the use of waste CO_2, thereby decreasing CO_2 emissions from CHP installations;
- support the development of geothermal energy use in the greenhouse sector;
- improve security of supply.

The Q16-Maas gas and condensate field currently operated by ONE, has the optimal location and size for this purpose. It is located just offshore, being operated onshore at the Maasvlakte area. After depletion, the reservoir will have a storage capacity of about 2 $MtCO_2$.

The seasonal buffer chain is being designed in collaboration with OCAP and ONE, optimizing the injection-production scheme to maximize buffer capacity and support growth in CO_2 offtake during the summer period. During winter the pure >99.9% CO_2 is delivered by the OCAP pipeline to the buffer site at a pressure of about 20 bar and a temperature of 10°C. Compression of the gas is needed for injection. After six months of injection, flow is reversed for six months of back-production in summer. The produced CO_2 will contain impurities such as CH_4, which need to be separated to comply with quality requirements for use in greenhouses. A techno-economic assessment will identify future scenarios in which geothermal energy combined with seasonal CO_2 storage will be an economically attractive alternative to the CHP. An evaluation of regulatory or other barriers will then define which (political) steps would be required for these scenarios to be practically achievable.

Mariëlle Koenen
Filip Neele
TNO

TNO innovation for life

Figure 1. Westland area of The Netherlands.

GeoEnergy Test Bed, UK

The UK GeoEnergy Test Bed (GTB), one of the ENOS field sites (Figure 2a), is a field laboratory founded by the University of Nottingham and the British Geological Survey. Research at the GTB will focus on fluid migration through natural pathways in the subsurface. The GTB was initiated with funding from the founding partners and has received capital investment from the UK Government Treasury as part of the Energy Research Accelerator (ERA) project. When completed, the GTB will be a national facility within ERA comprising an array of boreholes fully instrumented with advanced surface and sub-surface sensors.

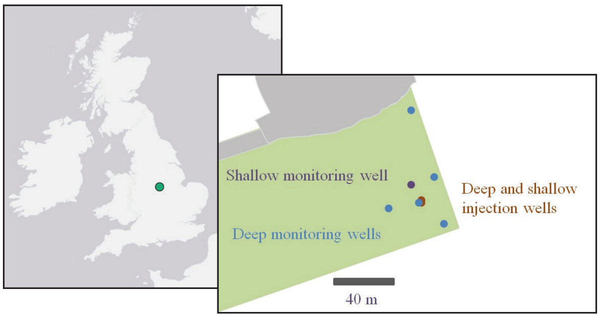

Figure 2a. Location of GTB (basemap OS data © Crown Copyright and database right 2017).

Figure 2b. Injection and monitoring well locations.

Construction started in November 2016 and the site is almost ready for commissioning; data collection using the advanced sensor network will begin soon. Downhole pressure, temperature, acoustic and electrical resistivity sensors installed in wells at depths of up to 270 m form a tight diamond-

Figure 3. Installing downhole sensors.

shaped array around the planned CO_2 injection well (Figures 2b, 3). An additional downhole microseismic array (detects tiny movements in the ground that can't be felt at surface) will be also installed in one well during April 2018. All the downhole sensors will be connected to the monitoring hut (Figure 4) in April/May 2018. Soil gas and flux sensors will be installed at the surface soon, completing the planned GTB 3D sensor array. After commissioning, geochemical and geophysical data will be continuously collected providing extensive detail on the properties of the

Figure 4. Pulling cables to connect the downhole sensors to the monitoring hut.

surface/subsurface within the sensor array. This sensor network will enable study of the subsurface volume of rock in exceptional detail, to examine the flow of fluids through natural pathways in shallow geological formations. This research will inform

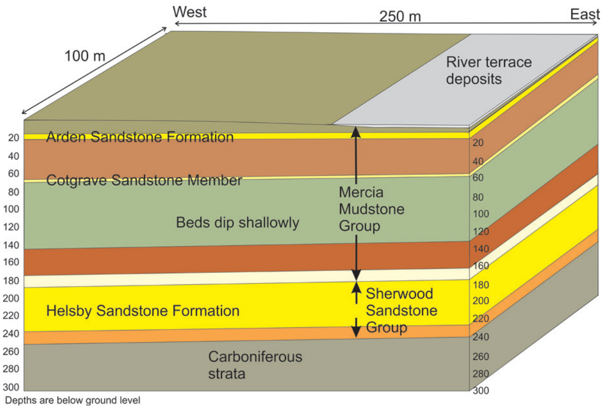

Figure 5. Simplified model of the geological formations at the GTB.

decisions about monitoring the zones above the storage reservoir (Figure 5).

The field laboratory will continue to evolve after this first major construction phase. The GTB will act as a hub to catalyse scientific collaboration between researchers from academic and industrial backgrounds. Research collaborations to develop new sensors and advance understanding of subsurface processes around fluid migration are invited. For example, there is scope to test new monitoring sensors under field conditions, to access fresh samples for laboratory testing and to work jointly on data collected at the site. Please contact Matthew Hall (Matthew.Hall@nottingham.ac.uk) and Ceri Vincent (cvi@bgs.ac.uk) for more information.

Ceri Vincent
British Geological Survey
Prof. Matthew Hall
University of Nottingham

ENOS

Work package 1. Ensuring safe storage operations

Coordinator: CIUDEN

Brine and CO_2 were injected into Hontomín's fractured low permeability reservoir using first discontinuous strategies. The geological model was updated using Petrel™. Preliminary seismic data processing and structural analysis were performed to obtain the baseline for risk control activities. Two deep sampling campaigns to analyze geochemical changes induced by the injection in the reservoir water, and a 3D VSP campaign around the injection well, with permanent optic fiber receivers using surface sources and cross-hole sparker survey were conducted. Installed soil gas stations are recording and transmitting data.

Work package 2. Ensuring storage capacities and cost-effective site characterisation

Coordinator: BRGM

BRGM has developed an approach to optimize the uncertainty related to the capacity estimate of CO_2 reservoirs using an existing geological model of the Paris Basin. Application of such approach is planned for ENOS sites. The Hontomin geological model has been provided by Geogreen for application of high resolution modeling by University of Nottingham. BGS has updated a 3D static model of the GeoEnergy TestBed site to be used by Heriot Watt University. CIUDEN has started to elaborate the Front-End Engineering Design study in collaboration with partners and an external German manufacturer.

Work package 3. Managing leakage risks for protection of the environment and groundwater

Coordinator: BGS

WP3 will advance monitoring tools and techniques that can identify, quantify and verify the source of CO_2 to demonstrate safe containment in deep storage sites. During the first 18 months of the ENOS project, partners tested new surface-based geochemical techniques at sites where CO_2 is naturally seeping to the surface. Testing of optic fibre tools in the laboratory and field began. Baseline data collection continued at the GeoEnergy Test Bed and began at Sulcis Fault Lab (SFL). Detailed design for SFL (including geophysical modelling and well design) also began.

Work package 4. Integration of CO_2 storage with local economic activities

Coordinator: TNO

Task 4.3 deals with building socio-economic models for a CO_2-EOR project in the LBr-1 field and seasonal buffering in the Q16-Maas field. The definition of the model concepts is largely finished, and development of the assessment tools in the Policy Support System IV simulator is ongoing. The innovations for analysing of the LBr-1 are an integrated analytical reservoir model and learning modes for reducing uncertainty. The analysis of Q-16 Maas goes even further, with the CO_2 supplier and user making independent decisions.

Work package 5. Coordination with local communities

Coordinator: UniRoma1

To facilitate the participation of civil society in the ENOS project, a set of informative sheets with original illustrations is now available on the ENOS website with the title "Participating in CO_2 Geological Storage Research" http://www.enos-project.eu/highlights/publication/participating-in-co2-geological-storage-research/. The first meeting with residents from the Rotterdam area took place in November 2017. Many questions were raised on how CO_2 storage technology works, how it can be applied, and how it differs from other geological activities like geothermal energy or oil and gas production.

Work package 6. International cooperation & seeding pilots and demos in Europe

Coordinator: CGS

Activities of ENOS Experience-sharing Focus Groups were started with a first workshop that defined the preferred topics for mutual exchange of experience among pilot CO_2 storage projects, and the first two webinars focusing on data management for CO_2 storage pilots and cost reductions through "smart" drilling. More information is available on the ENOS website. Proposals of new storage pilot opportunities in Europe were collected from European stakeholders, and six of them were selected by ENOS evaluators for support in the form of funding for a more detailed case study.

Work package 7. Spreading innovation

Coordinator: IRIS

WP7 arranged a knowledge integration workshop during the ENOS General Meeting in Orleans in October 2017. More than 40 participants formed five discussion groups, got familiar with each other`s area of expertise and discussed how to integrate activities across the work packages and competence areas. Promotion of the results, need and will to present complex research in simple and exciting way was high on the agenda. The ENOS end-user committee was formed and the first webinar presenting the plan for guideline documents was held on 31st January 2018.

Work package 8. Promoting CCS through education and training

Coordinator: GEUS

The first spring school for young scientists will be in May 2018 in Latera north of Rome. The CCS educational program also includes e-learning courses and short course for journalists (Venice, April). Joint International Professional Master Course on CCS is under approval in the involved universities and will first run in Sapienza University of Rome in 2019. For Master and PhD programmes (which will follow) the other ENOS partners will be involved by providing the students internships for their thesis. The Master degree will be issued as a joint title by each university.

Work package 9. Project management

The annual ENOS General Assembly, Knowledge Integration Workshop & WP meetings took place on 24-27th October 2017 in Orléans, France. The next project meeting will take place in autumn 2018 at one of the partner institutions.

Coordinator: BRGM

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Participating in CO_2 Geological Storage Research

To facilitate the participation of civil society in the ENOS project, a set of informative sheets with original illustrations has been produced and is now available on the ENOS website with the title "Participating in CO_2 Geological Storage Research". The technical themes and technologies that ENOS aims to develop are described, and the reader can find information on all the different aspects of the project, its research activities and their aims. Given the complexity of the topics, particular attention was given to find images that could be instantly digestible but at the same time accurate, complete, understandable and attractive. The illustrated material can be explored online or downloaded and is available in English, Italian and Spanish.

Samuela Vercelli
Sapienza University of Rome

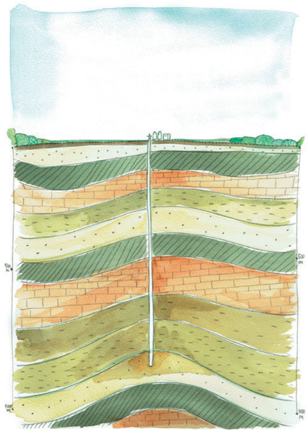

Figure 6. Imagination helps to grasp the reality of the underground and how CO_2 storage fits in it (image Sapienza University of Rome – CERI – CC BY NC ND).

ENOS partners

ENOS e-learning courses

ENOS builds awareness on climate change and opportunities for mitigation actions utilising CCS through e-learning courses

As part of the ENOS project, WP8 has developed an e-learning course on various aspects of CCS, containing basic knowledge (aimed at the general public), as well as specific technical knowledge on CO_2 storage, based on state-of-the-art understanding of ongoing R&D efforts (aimed at students or stakeholders). Altogether, the first two e-books containing nine of ten e-lectures are now available on the ENOS website.

The first e-book "Climate change and importance of CCS technology for decarbonisation of energy and industry" consists of two e-lectures:

- e-lecture 1: Climate change and energy consumption
- e-lecture 2: CCS as an option for CO_2 emissions reduction.

The second e-book "Geoscience applied to geological storage of CO_2" consists of seven e-lectures:

- e-lecture 3: Geological storage and trapping mechanisms
- e-lecture 4: Storage potential and capacity estimate
- e-lecture 5: Site selection and characterisation
- e-lecture 6: CO_2-EOR
- e-lecture 7: Storage risks
- e-lecture 8: Monitoring
- e-lecture 9: Numerical modelling of CO_2 storage.

Both e-books are PowerPoint based ppsx-files and published on the ENOS website. The lectures are self-explanatory and include test questions, allowing users to learn at their own pace and to check individual learning progress. E-learning for the broader community will help to build public awareness on climate change and mitigation action using CCS. The final e-book is expected later this year.

Stefan Knopf & Dorothee Rebscher, BGR
Niels Poulsen, GEUS

ENOS webinars

An important step in one of the key ENOS deliverables, the guidance documents, has been achieved. An end-user committee was established, and the second ENOS webinar was held on the 31st January 2018 to present the guidance documents concept. We encourage everyone to watch the webinar recording (http://www.enos-project.eu/highlights/webinars/webinar-n2-enos-best-practice-documents-and-end-users-participation_post/), fill in the questionnaire (https://goo.gl/forms/u66CdL6HWH3puQRp2) and join the end-user committee!

Come and talk to us at upcoming events

In the coming months you can meet ENOS researches at variety of different events:

- 13th CO_2GeoNet Open Forum in Venice 2018, 23-26 April
- (http://conference2018.co2geonet.com)
- Iberfault 2018, Alicante, 11-13 June (http://iberfault.org/en/start)
- GHGT-14, Melbourne, 21-26 October 2018 (http://www.ghgt.info)
- EAGE Fifth CO_2 Geological Storage Workshop, Utrecht, 21-23 November 2018 (https://events.eage.org/en/2018/fifth-co2-geological-storage-workshop)

ENOS publications

As work in ENOS progresses, its researchers have started to actively contribute to scientific publications. The highlights section of our website (www.enos-project.eu/highlights) contains the most up to date list of our publications which you can also download.

Materials are available on the ENOS website in the highlights section www.enos-project.eu/highlights

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