GEO ENeRGY

# Underground Hydrogen Storage – Underground Energy Storage

Energy storage is indispensable in the process of decarbonizing energy grids and replacing fossil fuels with intermittent renewable sources for energy production. There are currently many options/technologies for energy storage, from batteries to underground storage. From the available technologies involving the underground, hydrogen storage has the potential to become economically feasible in several years, since it can provide more than storing surplus energy: it can be used for methane production and thus have a commercial value.

The underground hydrogen storage technology is based on the worldwide experience in gas storage (natural gas and $CO_2$) and on the specific properties of gaseous hydrogen. At present there are 671 UGSs (Underground Gas Storage facilities) active worldwide (at the end of 2017, according to CEDIGAZ). Hydrogen has previously been stored in three salt caverns at Teesside in the UK since 1972 and in two at the US Gulf Coast in Texas since 1983.

Underground hydrogen storage is an element in the energy cycle (Figure 1): energy production from renewable sources → conversion into hydrogen → hydrogen storage → reconversion of hydrogen into other forms of energy → consumption of energy. The part of the cycle related to underground hydrogen storage comprises its transport from the site of its production (electrolysis) through a dedicated pipeline to the site of injection. The surface installation at the storage site includes sections for: compression, decompression, purification and dehydration. The underground part consists of an injection/extraction well with a subsurface installation and of a cavern created by dissolution (in the case of storage in salt deposits) or an enclosed structure in porous rocks — aquifer or depleted hydrocarbon field.

The following types of underground hydrogen storage types have been considered: aquifers, depleted hydrocarbon (natural gas and crude oil) fields, caverns mined in rock salt by dissolution, underground mine workings (abandoned salt or limestone mines) and rock caverns.

For the first three storage types, specific conditions for each type have to be met to make the adaptation for underground hydrogen storage (UHS) possible. The first two types are of pore-fracture type, where geological aspects and conditions are decisive for storage and the technical aspects are of secondary importance.

UGSs in depleted fields have been the most common type in the world. Such fields are usually already equipped with installations for the injection and withdrawal of gas and with systems of gas processing and preparation for transport in a transmission system. Consequently, the conversion of a depleted field into a UHS facility involves lower financial spending. In contrast, technical aspects and factors are important in cavern-type facilities, while limitations are provided by the transfer capacity of the surface installation.

The choice of geological structures for underground hydrogen storage should be based on a detailed geological analysis involving the evaluation of their usability, both on a basin scale and on a regional scale, the evaluation of storage capacity, the safety of long-term storage and other factors. The possibility of hydrogen escape and migration beyond the limits of the storage facility should be decisive for the rejection of hazardous locations. Criteria based on surface-related issues (hydrogen production, its transport and injection, and costs and profits) should be taken into account after the selection based on geological criteria.

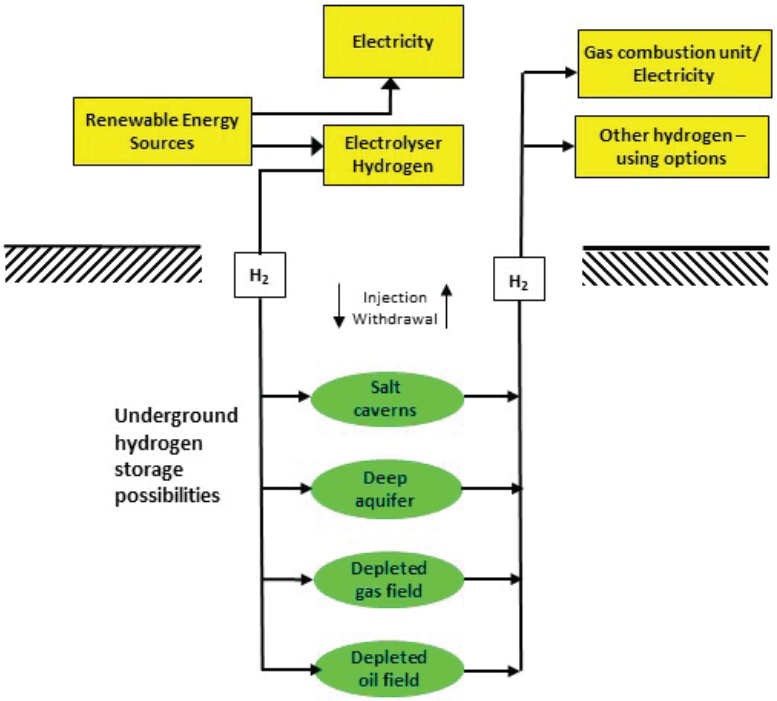


Figure 1. An energy system scheme with an underground hydrogen storage facility

**The Newsletter content**

Underground hydrogen storage is not yet a technically feasible means of storing energy, and this will still be the case for several years. Lowering the cost of hydrogen production by electrolysis will, in the future, be a decisive factor for implementation of this method of energy storage on an industrial scale.

The transformation of geological space into a space occupied by hydrogen will be a challenge for both the public and the private sector. Geological, technological, economic, legal and social obstacles will have to be overcome before the underground hydrogen storage is implemented on a full scale.

The full article can be accessed at:
https://www.sciencedirect.com/science/article/pii/S1364032119300528

Prof.
Radoslaw Tarkowski
MEERI PAS

# Introduction of New ENeRG Members

AGH University of Technology and Science conducts scientific and didactic activities in the field of geo-energy (geothermal energy, carbon dioxide storage, energy and hydrogen storage).

This activity is mainly carried out by employees of the Faculty of Geology, Geophysics and Environmental Protection, the Faculty of Drilling, Oil and Gas as well as the Faculty of Mining and Geoengineering. Works related to the recognition of the geothermal potential of Poland, including advanced geothermal systems, are being carried out, resulting in numerous publications, including: geothermal atlases of the Polish Lowlands, the Carpathian Foredeep and the Carpathians.

There are also studies on the use of shallow geothermal energy for heating and cooling. Issues concerning the efficiency of heat pumps and technological parameters for the operation of borehole heat exchangers constitute an important area of research. Efficiency tests are also conducted: heat storage in the rock mass, heat exchange in borehole heat exchangers, heat exchange with the rock mass and heat storage (e.g. waste heat). Research on hydrogen storage in geological structures (salt caverns, hydrocarbon fields and aquifers) is also being carried out.

Research is also being carried out on the geological storage and use of carbon dioxide. The research concerns the recognition of formation and structures for the safe geological storage of $CO_2$ and the possibility of $CO_2$ storage in the Baltic region.

An important direction of research is the mineral sequestration of carbon dioxide in fly ash from the combustion of hard and brown coal, and with the use of energy waste.

Research on geothermal energy and carbon dioxide storage is implemented within national projects (financed by the Ministry of Science and Higher Education and the Ministry of the Environment, National Center for Research and Development) and the KIC-InnoEnergy and Norway Grants projects.

More information can be accessed at:
https://www.agh.edu.pl/en/.

Barbara Uliasz-Misiak
D. Sc. PhD., prof. AGH

Hellenic Hydrocarbon Resources Management S.A. (HHRM S.A.) was established in 2011 and is headquartered in Athens. It is a state-owned company with the Hellenic State being the sole stakeholder (100%). However, it operates independently as a private-sector economic entity.

HHRM S.A. is a rapidly growing company providing an innovative and effective management in a wide spectrum of activities: Exploration & Production concessions, overview of the signed lease agreements, offshore safety, and active promotion of Greece as an attractive oil and gas destination to international investors. Its main targets are the contribution to the economic growth and energy independence, development of the geological knowledge of the country, support and promotion of research for the O&G industry and signing of agreements and ways to strengthen international relations.

The company has a unique technical knowledge of the key regions with high hydrocarbon prospectivity and can assist the industry in making more informed exploration decisions. So far, it has successfully proceeded to the assignment of onshore and offshore concessions (Ioannina, Arta – Preveza, Aitoloakarnania, NW Peloponnese, Katakolo, Patraikos Gulf, block 2 west of Corfu, block 10 in Kyparissia bay, Ionian, West of Crete and Southwest of Crete).

HHRM S.A. has also been transitionally appointed as the Competent Authority for Offshore Safety in Oil and Gas Operations in Greece since July 28th, 2016.

Its responsibilities include:
1) Assessing and accepting Reports on Major Hazards. Assessing design notifications and notifications of well operations or notifications of combined operations.
2) Overseeing compliance by operators and owners of the Greek Offshore Safety Law, including inspections, investigation and enforcement actions.
3) Advising other authorities or bodies.
4) Making annual plans and producing reports.
5) Cooperating with other EU Competent Authorities.
6) Proposing the issuing of safety regulations and regulatory acts.

HHRM S.A. welcomes interested investors to visit its proprietary data rooms and offers them the opportunity to examine high quality seismic imaging and legacy data, as well as to provide information about the licensing, legal and fiscal regime for oil and gas operations in Greece. The company is the sole proprietor of a data library comprising 179 wells, recently acquired offshore 2D seismic data, legacy reprocessed 2D and 3D offshore and onshore data, including both proven and frontier petroleum systems.

More information can be found at:
https://www.greekhydrocarbons.gr/.

Yannis Bassias
President & CEO of HHRM
Hellenic Hydrocarbons Resources Management S.A.

# $CO_2$ Capture and Utilisation in Pulverised Fly Ash (PFA) and production of zeolite

Coal is one of the most dominant energy resources of strategic importance in Europe. In 2017 it was mined in 41 regions across 12 EU countries, providing 240,000 job positions. Coal combustion is responsible for the production of 600-800 million tonnes/year of Pulverised Fly Ash (PFA) and for 46% of $CO_2$ emissions worldwide. To meet the Paris Agreement targets and keep global temperature rise below 2°C, EU countries are committed to drastically reduce $CO_2$ emissions. The produced fly ash can be used as material for $CO_2$ capture and Utilisation (CCU), either as it is or through pre-treatment.

COALBYPRO (Innovative management of COAL BY-PROducts leading also to $CO_2$ emissions reduction – www.coalbypro.eu) is a research project co-funded by the European Commission under the Research Fund for Coal and Steel (RFCS) for 3 years (2017-2020). The project aims to investigate new methods for the management of the coal/ lignite by-products to reduce the $CO_2$ emissions produced by fuel combustion.

The coal fly and bottom ash along with synthesized zeolites from coal fly ash are investigated as sorbents for carbon dioxide capture. COALBYPRO promotes $CO_2$ capture at the combustion site, minimising the transport cost of $CO_2$ to storage facilities. After $CO_2$ sorption, the final product can be used either as additive for construction mixtures or for landfilling or backfilling of mining galleries as the processed fly ash can increase the structural stability of the mine preventing, thus, land subsidence.

The countries engaged in COALBYPRO are Greece (CERTH – project coordinator), Czech Republic (VUHU, VSCHT, UJV), Germany (TU BAF) and Poland (GIG). The samples from the study areas have been characterised for their mineralogical, bulk chemical and physical properties. The first step was to identify the sorption properties of the fly ash samples and the produced zeolites through low (ambient) temperature adsorption experiments. The experiments showed that the unmodified samples have lower sorption capacities than the zeolites. The second step is the high temperature adsorption experiments. For this stage, the samples underwent another screening based on their content of Ca in reactive form. From the samples that continued to the experimental phase, and from results achieved up to now (ongoing research) Greek samples showed highest capacity after ten cycles followed by Czech samples.

The next steps of the project include the finalisation of the experiments (on the fly ash and the zeolitic samples) and running the experiment at industrial scale in an in-house built unit that will be directly connected with the flue gas. Finally, the products will be assessed for their leaching behaviour and a cost benefit analysis will be drawn in order to evaluate the feasibility of implementing the process at industrial scale.

Dr. Nikolaos Koukouzas
Director of Research CERTH

CERTH
CENTRE FOR RESEARCH & TECHNOLOGY HELLAS

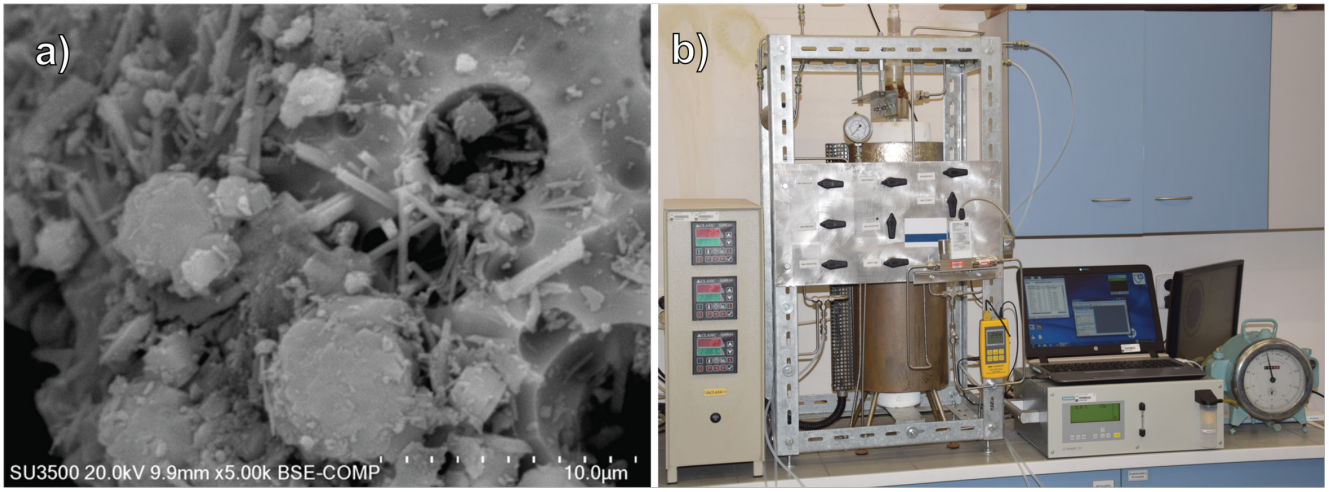


**Figure 2. a.** SEM/EDS analysis of a zeolitic sample from fly ash, **b.** High temperature apparatus with fluidised bed reactor.

**ENeRG – European Network for Research in Geo-Energy**

**ENeRG – European Network for Research in Geo-Energy** is an informal contact network open to all European organisations with a primary mission and objective to conduct basic and applied research and technological activities related to the exploration and production of energy sources derived from the Earth's crust.
**ENeRG president** is Dr. Vit Hladik from Czech Geological Survey, vit.hladik@geology.cz
**ENeRG secretariat** is run by Centre for Research and Technology Hellas, Athens, Greece
Contact person: Eleonora Manoukian, manoukian@certh.gr

**ENeRG website:** http://www.energnet.eu is maintained by Tallinn University of Technology,
Contact person: Dr. Alla Shogenova, alla.shogenova@taltech.ee

**ENeRG Newsletter – GEO ENeRGY**
The Newsletter is published by Department of $CO_2$ Geological Storage, GeoEcoMar, Romania.
Editor: Dr. Alexandra Dudu, alexandra.dudu@geoecomar.ro
Layout and computer typesetting: Point Media Concept SRL
Language review: Dr. Gillian E Pickup,
Heriot-Watt University, UK, G.Pickup@hw.ac.uk

# European Workshop on Underground Energy Storage
## 7-8 November 2019, Paris, France

### OVERVIEW

Energy storage will play a pivotal role in future energy systems compatible with a carbon-neutral and environmentally friendly society. It will enable to optimize the integration of renewable and recoverable energies into the electricity and heat mix and to contribute to the flexibility of energy systems, alongside improved grid interconnectivity, smart grids and demand-response functionalities.

Energy storage in the subsurface has the potential to become an important component of the transition to low carbon energy (http://www.energnet.eu/system/-files/documents/ENeRG_Position_Paper_2017.pdf ).
Storing energy underground can lead to larger-scale and longer-term solutions than above ground energy storage technologies, thus complementing the range of storage technologies to be able to meet very diverse needs.

The objectives of the workshop are to discuss current technological status and research needs for the development of the subsurface energy storage technologies (Figure 3), and to encourage exchange between energy producers and consumers who need energy storage solutions.

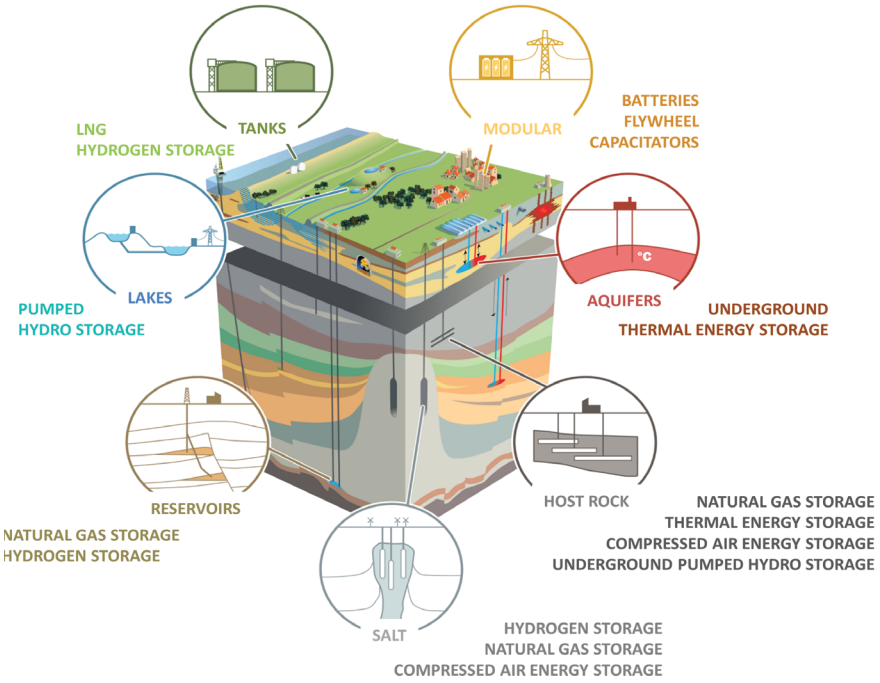


Figure 3. Main types of above ground and subsurface energy storage (Figure from the ESTMAP European project http://www.estmap.eu/)

### ORGANISERS

This European workshop on Underground Energy Storage is organised by ENeRG, in collaboration with:
• EuroGeoSurveys' GeoEnergy Expert Group (http://www.eurogeosurveys.org/-expertgroups/geoenergy/)
• the ANR FLUIDSTORY project https://anr.fr/Projet-ANR-15-CE06-0015
• BRGM (https://www.brgm.eu/), the French Geological Survey
The workshop is organised in Paris as a back-to-back event with the national energy storage days organised each year by the Energy Storage Club of ATEE http://atee.fr/stockage-énergie, the French Technical Association on Energy and Environment:
• 5-6 November: ATEE Days on Energy Storage (language: French)
• 7-8 November: European workshop on Underground Energy Storage (language: English)
Attendance to both events is encouraged.

### TOPICS

- Demand for underground energy storage in tomorrow's energy systems
- Storage in cavities, old mines, depleted hydrocarbon reservoirs, aquifers, rock
- Potential of technologies
- Case studies
- Pilot and demo projects
- Risks and environmental impacts
- Geological, technological, economical, legal, social issues

### REGISTRATION

Free of charge.
Registration will open early September. Please check the ENeRG website.

### CONTACT

Dr. Isabelle Czernichowski-Lauriol,
BRGM, French representative of ENeRG
Email: i.czernichowski@brgm.fr

Geoscience for a sustainable Earth
brgm

### ENeRG members

**University of Tuzla** (Bosnia and Herzegovina)
Prof Sanel Nuhanovic
sanel.nuhanovic@untz.ba

**Sofia University** (Bulgaria)
Prof Georgi V. Georgiev
gigeor@abv.bg

**University of Zagreb** (Croatia)
Prof Bruno Saftic
bruno.saftic@rgn.hr

**Croatian Geological Survey** (Croatia)
Dr Staša Borovic
sborovic@hgi-cgs.hr

**Czech Geological Survey** (Czech Republic)
Dr Vit Hladik
vit.hladik@geology.cz

**GEUS - Geological Survey of Denmark and Greenland** (Denmark)
Dr Niels E. Poulsen
nep@geus.dk

**Department of Geology, Tallinn University of Technology** (Estonia)
Dr Alla Shogenova
alla.shogenova@taltech.ee

**BRGM** (France)
Dr Isabelle Czernichowski-Lauriol
i.czernichowski@brgm.fr

**H.S.G.M.E. - Hellenic Survey of Geology and Mineral Exploration** (Greece)
Dr Apostolos Arvanitis
arvanitis@igme.gr

**CERTH** (Greece)
Dr Nikolaos Koukouzas
koukouzas@certh.gr

**Hellenic Hydrocarbon Resources Management S.A.** (Greece)
Yannis Bassias
y.bassias@greekhydrocarbons.gr

**OGS - National Institute of Oceanography and Experimental Geophysics** (Italy)
Ing Sergio Persoglia
spersoglia@ogs.trieste.it

**Nature Research Centre** (Lithuania)
Prof. Saulius Sliaupa
sliaupa@geo.lt

**Institute of Geology and Seismology** (Moldova)
Dr Igor Nicoara
nicoaraigor@gmail.com

**Polish Geological Institute** (Poland)
Dr Adam Wojcicki
awojci@pgi.gov.pl

**MEERI PAS** (Poland)
Prof Radoslaw Tarkowski
tarkowski@min-pan.krakow.pl

**AGH University of Technology and Science** (Poland)
Barbara Uliasz-Misiak
uliasz@agh.edu.pl

**National Institute for Marine Geology and Geoecology-GeoEcoMar** (Romania)
Dr Constantin S. Sava
savac@geoecomar.ro

**VNIGRI** (Russia)
Prof Alexander Ilinsky
alex.ilinsky@bk.ru

**GEOINŽENIRING d.o.o.** (Slovenia)
Marjeta Car
m.car@geo-inz.si

**Middle East Technical University, Petroleum Research Center** (Turkey)
Dr Çağlar Sinayuç
caglars@metu.edu.tr

**Heriot-Watt University** (UK)
Dr Gillian Pickup
G.Pickup@hw.ac.uk