ENeRG Position Paper September 2014

Integrated and Sustainable Energy Uses of the Underground

ENeRG - (European Network for Research in Geo-Energy) includes members from 29 European countries and has long experience in basic and applied research and technological activities related to exploration and production of the underground energy sources, CO_2 and natural gas storage within many national and international projects.

Current situation. The underground is used for multiple purposes including potable water production, rock mining, hydrocarbon exploration and production, geothermal energy production, waste disposal, CO_2 storage, natural gas and other energy storage options. Most commonly the underground is explored and used locally for one, sometimes for several of these resources. Multiple use of the underground may have synergies but also conflicts of interests and may not be supported by available technologies and regulations in many countries.

Future demands and the role of the energy. By 2030 Europe could be generating more than 40% of its energy from renewables, using 38% less energy than in 2005 and emitting 50% less greenhouse gases than it did in 1990. Europe could be on track to deliver a 100% renewably powered energy system by 2050. Many of the green-energy and low-emission technologies exist today but need to be developed and expanded further. Besides cutting the vast majority of its emissions, Europe could also reduce its use of key resources like oil and gas, raw materials, land and water. Integrated use of the underground supports these future European targets.

Purpose of the Position Paper: EU Energy Roadmap 2050[1] is focused on challenges posed on the European energy sector by the EU commitment to reduce greenhouse gas emissions to 80-95 % below 1990 levels. This decarbonisation objective has to go hand in hand with the requirements of security of supply and competitiveness at the same time, which is not an easy target. The Roadmap examines several scenarios of possible development, and all of them include geo-energy-related issues appearing for new and re-focused efforts in geo-energy research. Combating climate change as one of the global challenges also provides a unique opportunity to shift to a sustainable, low-carbon economy.[2] The purpose of the Position Paper is to give guidance on new research needed for integrated and sustainable use of the underground in relation to natural gas (shale gas, coal-bed methane, gas hydrates), shale oil (kerogen oil), geothermal energy, CO_2 capture and storage (CCS), CO_2 capture, utilization and storage (CCUS), nuclear energy and waste disposal, and energy storage, while preserving groundwater.

Geothermal energy is a non-intermittent renewable energy. Underground resources range from shallow resources, through deep permeable aquifer reservoirs, hot springs, fumaroles, geysers, travertine deposits, chemically altered rocks to hot dry rocks. The main goal for geothermal exploration research is to significantly enhance the production from existing resources and to identify new resources including all forms of geothermal energy e.g. heating, cooling and electricity production options, depending on the local needs, possibilities and geological conditions. The assessment of the geothermal potential is, however, usually subject to great uncertainty due to a lack of sufficient reservoir data in the area of interest. In order to identify possible future production areas of geothermal energy, it is necessary to supplement the existing knowledge with new research. Despite the good overall understanding of the subsurface, a number of unknown factors remain for successful geothermal exploitation due to the geological heterogeneity, lateral and vertical lithology variations, faults, diagenesis reducing porosity and permeability, scaling and corrosion. Research is needed to improve the economic risk assessment and management for reliable technical, environmental and economically sustainable projects by new and improved geological models, combining all geophysical and geological data to refine and predict the right geological conditions and factors present for geothermal exploration, and especially better and cheaper drilling techniques. Moreover, research is also needed to gain better understanding of how much geothermal energy we can expect to produce,

---

[1] EC Communication COM, 885/2, December 2011

[2] Horizon 2020 Work Programme 2014-2015

and to find the best ways of efficient and sustainable exploitation. Enhanced Geothermal System is a new type of geothermal power technology that does not require natural convective hydrothermal resources. Until recently, geothermal power systems have exploited only resources where naturally occurring heat, water, and rock permeability are sufficient to allow energy extraction. Research areas are evaluation of various types of resources, drilling and stimulation technologies, exploitation techniques and new wells' architectures, maintenance and monitoring, effluent valorization, energy optimization and environmental impact assessment.

Mapping of very shallow geothermal energy potential in terms of thermal conductivity all over Europe can contribute to the further development of geothermal heat pump application/usage.

Fossil fuels. Even if the role of fossil fuels is expected to decrease in future, natural gas will play an important role in the transformation of the energy system in the short to medium terms. Taking this into account, the EU natural gas resources gain importance, especially when speaking about unconventional resources like shale gas, tight gas, coal-bed methane, or gas hydrates. Possible exploitation of all of these deposits requires much more research and development efforts than has been spent on it so far. The recent, mostly unexpected boom of shale gas exploration in many European countries, that has caught the majority of European regulatory authorities and the geo-energy research community on the wrong foot, is clear evidence that the attention paid to research on fossil fuels, and natural gas in particular, has to increase in future. Only through focused R&D activities, even supported by small pilot experiments, the burning issues of risks, safety, groundwater protection, accompanying the exploration of these unconventional deposits can be reliably assessed without turning them into emotional or even political issues.

Natural gas exploitation of all kinds of deposits including unconventional resources requires in Europe much more research and development efforts.

Shale gas deposits are considered unconventional gas resources that can be found in very low permeability shales. Following major international projections, gas will play a very relevant role in the future energy mix. There is a strong interest in the identification of potential shale gas objectives in Europe. Some systematic approaches that have been carried out in European geological basins based on literature review are offering very promising perspectives for exploration and production and especially in some countries such as Poland and France that hold about half of the estimated gas resources in place in Europe, or the United Kingdom, where the government has introduced important support to shale gas exploration. These perspectives need to be confirmed by concrete exploration as it's currently the case in Poland, where the estimated resources are revised after the first tests (-30% at the minimum). If the use of these resources becomes a reality, European dependence on gas from Russia and the Middle East could be reduced, having an impact on economic and political questions. Risks understanding, monitoring and mitigation of impacts, including microseismicity posed by hydraulic fracturing for unconventional hydrocarbon extraction, and improvement of general public confidence are critical issues for technology implementation.

Research for better understanding of the fundamental processes and risks, monitoring and mitigation of impacts posed by hydraulic fracturing is needed.

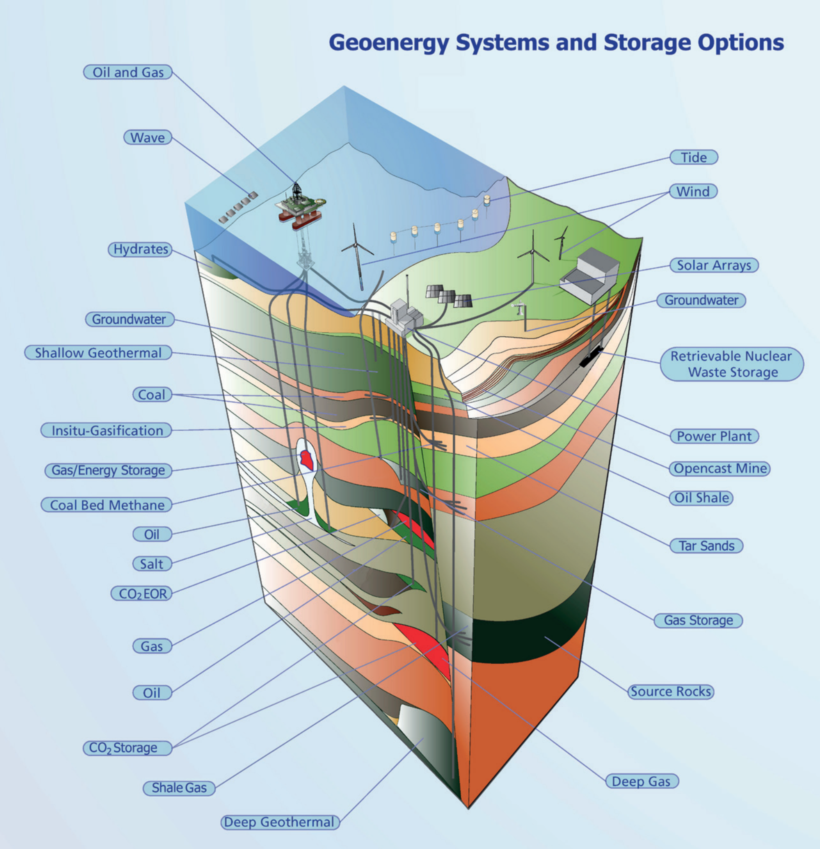
Coal-bed methane. Enhanced coal bed methane recovery (ECBMR) and underground coal gasification (UCG) address to the 'zero emission' use of coal if combined with CCS and the use of abandoned coalfields or unminable coal seams. The advantages of combined underground coal gasification and coal-bed methane recovery with CCS (UCG-CCS) are due to the fact this is an 'economic' use of CO_2 provided by moderate emission sources nearby. The storage capacities are known to be far lower than in saline aquifers and even in comparison with depleted hydrocarbon fields. However, development of ECBMR and UCG technologies in Europe may lead to wide application in emerging economies with very high potential of gas production. The most critical and prospective research areas are environmental issues, potential groundwater contamination, subsidence impacts and conflict of interests and biogenic methane generation from CO_2 in coal beds.

The most critical research areas for coal bed methane are environmental issues, potential groundwater contamination and conflict of interests in the use of the underground.

Natural gas hydrates. Estimates of natural gas in the form of gas hydrates in land permafrost and in offshore deep sediments double all known fossil fuel reserves which makes hydrates a strong candidate as future energy source. Many governments (Japan, Korea, India, US, Norway, etc.) support the research on gas hydrates, and industry is looking for ways of using hydrate as gas storage and transportation medium as well. "Permafrost and gas hydrate related methane release in the Arctic impacts on climate change: European cooperation for long- monitoring" is a theme of the COST project PERGAMON. New research is needed to determine common procedures to estimate the distribution and the amount of methane (as free gas and gas hydrate) by geophysical methods, to quantify the methane input from marine sources into the atmosphere and ultimately to evaluate the impact of methane seepage on the global climate; to study the origin and type of different methane sources (dissolved/free gas, gas hydrate); to develop new tools, methodologies and approaches for better understanding the processes regulating the methane system.

Research of the origin and type of different methane sources, their influence on climate, and processes regulating the methane system is needed.

Shale oil refers to kerogen oil obtained by destructive retorting of oil shale. About 100-200 litres of oil can be produced from one tonne of commercial grade oil shale. Ex-situ production of shale-oil is accompanied by retort gas, ash and CO_2 production. At the present time China, Estonia and Brazil are producing shale oil ex-situ. Testing of in-situ shale oil production is ongoing now in Israel, ex-situ projects are under developing in Jordan and USA.



The future research should be targeted on the most environmentally friendly technologies for using of oil shale ex-situ and in-situ.

CO_2 storage in the deep underground is important part of the CCS technology, related not only to coal and gas fired power plants, but also to CO_2 point sources (chemical, petrochemical, paper, steel or cementplants) and to bioenergy leading to scenarios with negative emissions. All these plants deliver products that we cannot do without even in 2050, but at the same time, are highly energy- and CO_2-intensive. They utilise one-third of global energy, most of which is gained from fossil fuels, and make up to 40% of total CO_2 emissions worldwide. Demand for industrial goods is expected to at least double by 2050, and without renewables, nuclear or CCS the share of industrial CO_2 emissions will be up to 90% by 2050.To fight global warming, many countries are looking at technological solutions to decrease the release of CO_2 in the atmosphere. A bottleneck in CCS involves making all steps possible at the same time: separating the CO_2 from the gases produced by large point sources, transporting it to the location of use or storage, injecting it into deep underground geological formations. The science and technology behind CCS has been already manifested and has been in use for enhanced oil recovery (EOR) since the 1960s and for CO_2 geological storage since 1996. The famous Sleipner project, is only injecting 1 Mt of CO_2 annually. To reach the 2050 goal, we need about 2000 Sleipners by 2050, and therefore more R&D is needed within capture, transport, storage (including storage site mapping) and risk management.

Research is needed to collect newer data to create the "European CO_2 Storage Atlas", for integration of CO_2 utilization with CO_2 storage and synergies with geothermal energy exploitation.

Nuclear energy and waste disposal. Nuclear energy is expected to play an increasingly important role in the future energy mix in Europe (see e.g. IEA). Therefore, the disposal of spent nuclear fuel and reactor waste (low and medium-level waste) is an important issue. The development in the nuclear waste management has been diverse in EU countries. While the first countries are planning to start geological disposal in the 2020s, some others lack political and legislative guidelines. To ensure safe disposal of nuclear waste, the EC passed the Directive 2011/70/EURATOM. It is expected that after bringing into force the members' states laws, many countries will start extensive geoscientific and technical research programmes aiming to solve the specific questions related to the implementation of their waste disposal. Mapping of possible storage sites in different geological settings, their geoscientific characterization and testing, numerical modelling and simulations of coupled thermo-hydro-mechanical processes related to underground repositories are important research areas. The safety assessment and the long-term safety topics in general are the fundamentals in the geological disposal concept and plenty of effort is made to comply with safety standards provided by the regulators. Transparency and professional and unbiased participation of researchers can positively influence the public opinion on this politically sensitive technology. Furthermore, environmentally safe mining of radioactive ores should not be underestimated.

Research contributing to the secure and environmentally safe uranium mining and safe disposal of radioactive or other waste in geological repositories will be essential to social acceptance of future use of nuclear energy.

Energy storage is a very new and important challenge opening a new research domain which will play an increasingly important role in enabling the EU to develop a low-carbon electricity system. Increasing use of renewable energy sources (RES) for energy production (up to 20% to 2020 and much more in the following decades), largely coming from wind and solar power generation, and highly influenced by fluctuations in the weather, is causing a need for massive storage of electric energy. Electric energy storage technologies involving the use of underground offer large storage capacities and discharge rates. Among the options for large-scale storage in the underground are (i) underground pumped hydro-storage (UPHS), (ii) compressed air energy storage (CAES), and (iii) hydrogen storage from conversion power to gas. Each of these techniques requires the selection of appropriate geological formations (leached salt caverns, crystalline rocks, sedimentary porous rock, porous basalts, abandoned mines or natural underground cavities). To date, there are worldwide only few existing plants for electric energy storage using the underground (e.g. the CAES plants located in Germany and in USA). Aquifer thermal energy storage (ATES) could be also mentioned, but this only applies to single building or to local heat grids.

Mapping of all possible underground energy storage sites, estimation of their storage capacity, techno-economic feasibility and the short and long term market perspectives are important future research areas.

Integrated use of the underground. The underground offers both many resources and storage opportunities, and research is needed for development. Sharing tools and geological information on generic/common issues (e.g. 3D geological mapping, understanding hydro-thermo-chemical-mechanical and biochemical processes) will give synergies between various uses and can avoid conflicts in the utilization of the underground. Groundwater is the most important resource for people, agriculture and industry. At the same time it is the most vulnerable resource in the world, as it is influenced by climate change, agriculture, industrial and human activities. Management of the water resources is regulated by the Groundwater Directive and national regulations, and it is always necessary to consider groundwater first priority during integrated use of the underground. Possible influence of any underground activities on the groundwater should be estimated and modelled by research and avoided before any underground use. The groundwater monitoring and research should accompany all demonstration and industrial projects using the underground. A new concept of an integrated underground storage atlas should include storage options for all range of possible stored media, such as natural gas, CO_2, energy or waste materials, and should include available infrastructure in connection to these media (natural gas pipelines, CO_2 emission sources, renewable energy sources, electrical grids, abandoned mines, depleted oil fields, nuclear power plants, etc.). The underground can be used for several purposes at the same site, but the depth, technical and economic requirements for various uses are often different. Preferred underground depth, temperature and pressure, water salinity, thickness of the reservoir and cap rocks, their porosity and permeability, internal and external structure of the storage site should be studied in details. In this case, the shallowest resources are potable water and shallow geothermal energy, followed by gas storage, CO_2 storage and deep geothermal energy, which potential is increasing with depth. CO_2 capture, utilization and storage (CCUS) give new advanced options for synergy between CCS, hydrocarbons, heat and geothermal energy production using the same underground space. CCUS could offer a low-cost stepping stone for fossil fuel independency. The use of the underground for several purposes at the same time may cause conflict of priority, but they also could be applied in synergy.

Detailed exploration of the underground structures, properties of reservoir and sealing rocks, estimation of the storage capacity and 3D models of the studied underground space are needed to take decision about the most economic use of the subsurface and multiple or integrated use of the underground.