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CO_2 storage

Geological storage of CO_2: a viable solution to mitigate climate change? Storage options, potentials and obstacles in Hungary

G. György FALUS*, Kálmán TÖRÖK*, Mária HÁMOR-VIDÓ*, Endre HEGEDŰS*, Ágnes SZAMOSFALVI*, Henrietta JENCSEL*

Carbon dioxide storage is better and better concerned on international level as a viable option to mitigate climate change. However, for a site being acceptable for CO_2 storage some basic, geological related criteria has to be fulfilled.

Hungary has annual stationary point source CO_2 emissions around 23 Mt, of which more than 70% is related to the energy sector. According to recent assessment of storage potential, more than 4000 Mt of CO_2 could be stored in the subsurface.

Keywords: hydrocarbons, coal, climate change

1. General issues

Increasing awareness of climate change attracts more and more economic and political stakeholders to think about carbon dioxide capture and geological storage (CCS) as a possible option to effectively cut greenhouse gas emissions. Current studies univocally state, that drastic changes have to be made in our energy systems to mitigate the effects of climate change. This means, that besides considerably increasing energy efficiency, fossil fuels would have to be replaced by renewables in a very short time period. Although the necessity of this replacement is indisputable the very short time period does not seem realistic from technological and economic viewpoint. Consequently, the only available bridging methodology in the next few decades to fulfill ambitious goals in drastic emission cuts is the application of CCS technologies.

* Eötvös Loránd Geophysical Institute of Hungary, H-1145 Budapest, Kolumbusz u. 17-23, Hungary

Injection of CO_2 to saline formations in sedimentary basins is one of the most promising methods of geological storage of CO_2 for the long-term sequestration of the gas. This is because saline formations are very common in sedimentary basins, they have enough capacity to store large amounts of industrial CO_2, and there are shorter distances between most large CO_2 point sources and saline formations, which can minimize CO_2 transportation costs. The injected CO_2 is stored by three trapping mechanisms in saline formations:

— CO_2 can be trapped as a gas or supercritical fluid in a formation, commonly called hydrodynamic trapping.

— CO_2 can dissolve into the groundwater, referred to as solubility trapping. The dissolution of CO_2 in groundwater increases the acidity of water and affects the dissolution of minerals composing the host rock matrix.

— CO_2 can react directly or indirectly with minerals in the geologic formation leading to the precipitation of secondary carbonates. This process is called 'mineral trapping', which could immobilize CO_2 for long-time scales, and prevent its return to the atmosphere.

For a site being suitable for CO_2 storage some basic, geological related criteria has to be fulfilled [CHADWICK et al. 2006]. These are:

a) Sufficient depth of reservoir to ensure that CO_2 reaches its super-critical dense phase but not so deep that permeability and porosity is too low.

b) Integrity of seal to hinder CO_2 escape.

c) Sufficient CO_2 storage capacity to hold the CO_2 expected to be released from the source.

d) Effective petrophysic reservoir properties to ensure CO_2 injectivity to be economically viable and that sufficient CO_2 can be obtained.

Fulfillment of these basic criteria depends on the values of several geological and physical parameters. In the search for suitable sites for CO_2 storage it is therefore important to estimate if the basic criteria listed above and their associated geological and physical parameters are fulfilled. The first step in a site selection process, which has been carried out by the Eötvös Loránd Geophysical Institute of Hungary in national and FP6 EU projects is the screening of sedimentary basins in Hungary for CO_2 storage potential.

2. Carbon dioxide emission in Hungary

Having a view on the emission statistics of 2005, the largest CO_2 emission in Hungary is related to the energy sector (*Fig. 1*), which is responsible for 33% of total emissions (~80 Mt) and almost 73% of the emissions by large point sources. Cement industry and oil refineries also represent important emission sources being responsible for around 13% of point source related emissions.

In the short and medium term no cuts in emission are expected in Hungary. In fact, in certain scenarios, emissions in some industrial sectors may even show an increase in the medium term. The demand for an alternative solution for decreasing the emissions, namely carbon dioxide capture and geological storage are expected in this field.

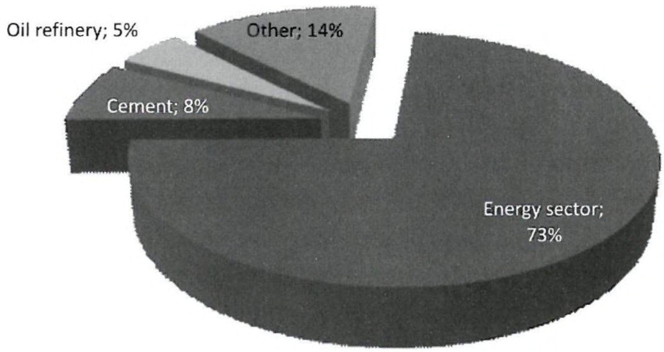

Fig. 1. Carbon dioxide emission in Hungary (2005)
1. ábra. Széndioxid kibocsátás Magyarországon (2005)

3. General storage options

Carbon dioxide, after being captured from an emission source, can be either stored or re-used. Because of limited market use, the majority of extracted CO_2 needs to be stored. CO_2 can be stored in geologic formations (including depleted oil and gas reservoirs, deep saline aquifers and unminable coal seams). CO_2 can also be fixated in the form of minerals. Geologic formations offer a huge storage capacity. Despite the broad ranges in the storage capacity, it can be concluded that the capacity is sufficient to store worldwide man-made CO_2 emissions for tens and possibly hundreds of years.

Oil and gas reservoirs, which generally have been well researched, are considered to be safe sinks for CO_2 storage, since these reservoirs have held oil, gas and often CO_2 for millions of years. CO_2 injection in some of these reservoirs will enable further production of oil/gas remaining in the reservoir. The revenues from this additional oil/gas could be used to offset the cost of CO_2 storage. This process, referred to as enhanced oil/gas recovery (EOR), has been performed in the USA using CO_2 for some years, not with the purpose of CO_2 storage, but to increase oil production. In Canada, injection of acid gas (a residual product of natural gas refining consisting of mainly CO_2 and H_2S) into oil/gas fields and deep saline aquifers has been practised for many years.

Deep saline aquifers are underground formations, typically sand-stones, containing saline water. These formations offer enormous storage potential: they are present in most countries, often close to industrial CO_2 sources, are usually very large, and so have a very large CO_2 storage capacity. The injection of CO_2 into these formations is similar to injection into oil and gas fields. The Norwegian Sleipner project, the first commercial CO_2 injection project in the world, where annually circa one million tons of CO_2 is injected into an aquifer under the North Sea, demonstrates that CO_2 can effectively be stored in large quantities.

Underground coal layers sometimes cannot be mined, being too thin or too deep. They usually also contain certain amounts of methane gas. When injecting CO_2 in a coal seam, it has been shown that CO_2 'sticks' better to coal than methane does, so it sets the methane free. This means that the coal layer becomes a producer of natural gas, which can be sold to offset the costs of CO_2 storage. Coal seams have held methane for millions of years, so it is quite probable that they will retain CO_2 for at least thousands of years. This storage technology is being tested in the EU RECOPOL project, with a field experiment in Poland.

4. Storage options in Hungary

According to preliminary studies, carried out in the frame of EU-funded CASTOR and GeoCapacity and national projects, Hungary's potential in geological storage of carbon dioxide is remarkable. Potential formations are similar to those, discussed above, namely depleted hydrocarbon reservoirs, deep saline aquifers and unminable coal seams. In case of hydrocarbon reservoir and coal layer storage of carbon dioxide there is an option to extract additional oil or methane stored in the layers, respectively. This could offset high costs related to CO_2 capture.

In the following section an estimation of the storage capacity of potential storage sites is given:

Hydrocarbon reservoirs

Public data used for the preliminary estimation of storage capacity of hydrocarbon reservoirs is derived from the Hungarian Bureau of Mining and Geology. Distribution of hydrocarbon fields is shown below in *Fig. 2*. The estimations are based on production data of the 10 largest oil and gas reservoirs which provide about 80% of the total production. The reservoirs are mainly Upper Miocene sands, however, karstic and metamorphic reservoirs also exist.

The estimated amount of CO_2 that could be theoretically stored in the hydrocarbon reservoirs is about 470 million tons.

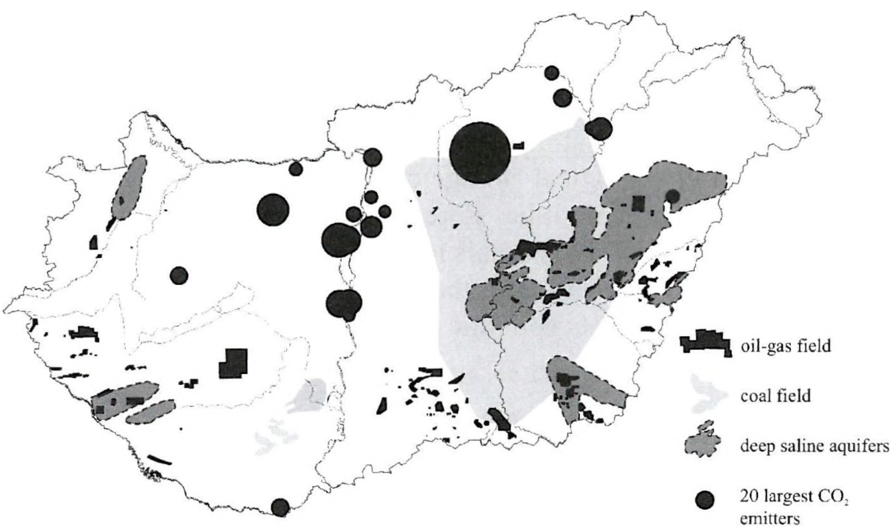

Fig. 2. Cumulative storage capacity in Hungary
2. ábra. Tárolási kapacitás Magyarországon

Coal seams

The minimum depth required to store carbon dioxide in coal layers is 400 meters. Based on this limiting factor, there are three coal fields in Hungary that are potentially available for CO_2 storage: the Mecsek Coal Formation with Lower Jurrasic age, in southern Hungary and the Toronyi and Bükkalja Lignite Formation in western and central Hungary, respectively, with upper Miocene age. The bulk storage capacity of the coal formations is between 60–600 million tons depending on, whether lignites are capable of permanent CO_2 storage or not.

Deep saline aquifers

Deep saline aquifers represent the largest carbon dioxide storage potential worldwide. Storage can be realized below 800 m depths in aquifers that contain water which is not suitable for drinking, or any other purposes (i.e., geothermal applications, etc.).

Concerning the deep aquifers in Hungary, only a very preliminary database exists and more detailed study is necessary to have a clearer view on storage capacity in this type of geological formations. Based on the preliminary estimations the storage capacity in Hungarian deep saline aquifers is estimated to be 3000 to 5000 million tons.

Cumulative storage capacity in Hungary

The first estimation of storage capacity demonstrated that Hungary has a large potential in geological storage of CO_2. The results show that the amount of CO_2 that could be stored in the subsurface amounts to 4000–6000 million tons. This equals to 100–200 years of all point-source emissions in Hungary and indicates that carbon dioxide storage in Hungary could become a significant economic potential of our country.

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A CO_2 földtani tárolása: a klimaváltozás csökkentésének életképes megoldása? Tárolási feltételek, potenciál és akadályok Magyarországon

FALUS G. György, TÖRÖK Kálmán, HÁMOR-VIDÓ Mária, HEGEDŰS Endre, SZAMOSFALVI Ágnes, JENCSEL Henrietta

A széndioxid tárolását egyre inkább a klimaváltozás csökkentésének lehetséges megoldásának látják nemzetközileg. Azonban a széndioxid tárolására alkalmas tárolónak néhány alapvető, földtani vonatkozású feltételnek meg kell felelnie.

Magyarországon az éves stacionárius pontforrásból eredő széndioxid kibocsátás közel 23 Mt, melynek több, mint 70%-a az eneregiaszektorból ered. A tárolási kapacitás legfrissebb felmérése szereint a föld alatt több, mint 4000 Mt CO_2 tárolásra van lehetőség.