

## Carbon Storage

**C**arbon dioxide (CO<sub>2</sub>) storage is the placement of CO<sub>2</sub> into a subsurface formation or ecosystem in such a way that it will remain permanently stored and not be released to the atmosphere. Numerous studies suggest there is extensive worldwide potential for permanently storing large quantities of CO<sub>2</sub> in geological formations; estimates currently range between 2 trillion and 11 trillion metric tons.

### GEOLOGIC FORMATIONS

Geologic formations considered for CO<sub>2</sub> storage are layers of porous rock deep underground that are “capped” by a layer or multiple layers of non-porous rock above them. In order to do this, a well is drilled down into the porous rock and pressurized CO<sub>2</sub> (compressed into a liquid-like state called “supercritical fluid”) is injected into it. Once injected, the CO<sub>2</sub> tends to be buoyant and will flow upward until it encounters a barrier of non-porous rock, which traps the CO<sub>2</sub> much the way oil, gas, and natural CO<sub>2</sub> have been confined underground for millions of years. Over time, other trapping mechanisms (such as saline water formations, where CO<sub>2</sub> can be dissolved and trapped indefinitely; and chemical binding to certain types of rock) also take effect.

There are three priority types of geologic formations in which CO<sub>2</sub> can be stored:

1. **Depleted Oil and Gas Reservoirs:** These are formations that once held crude oil and natural gas. In general, they are a layer of porous rock with a layer of non-porous rock above, which forms a dome. It is the dome shape that trapped the crude oil and natural gas. This same dome offers great potential to trap CO<sub>2</sub>.

As a value-added benefit, CO<sub>2</sub> injected into a depleting oil reservoir can enable recovery of additional oil. Oil companies have more than 40 years of experience of using injected CO<sub>2</sub> to “push” oil toward producing wells using Enhanced Oil Recovery (EOR). When injected into a depleted oil bearing formation, the CO<sub>2</sub> dissolves in the trapped oil and reduces its viscosity, or “thickness.” This “frees” more of the oil by improving its ability to move through the pores in the rock and flow with a pressure differential toward a recovery well. This can increase oil recovery from the well by an additional 10–15 percent.

2. **Unmineable Coal Seams:** Unmineable coal seams are too deep or too thin to be mined economically. All coals have varying amounts of methane absorbed onto pore surfaces, and wells can be drilled into unmineable coalbeds to recover this coalbed methane (CBM), which is an energy resource similar to natural gas. Because coal has an affinity to preferentially absorb carbon dioxide over methane, injecting CO<sub>2</sub> into unmineable coal seams can lead to enhanced recovery of CBM. One study of the Central Appalachian Basin in the United States estimates that more than 1.3 billion tons of CO<sub>2</sub> can be stored while yielding an increase in CBM reserves of as much as 2.5 trillion cubic feet, due to enhanced recovery.



- 3. Saline Formations:** Saline formations are layers of porous rock that are saturated with highly mineralized brine (extremely salty water) unsuitable for agriculture or human consumption. They are much more commonplace than coal seams or oil and gas bearing rock, and represent an enormous potential for CO<sub>2</sub> storage capacity. However, there is significantly less characterization of saline formations than there is of crude oil reservoirs and coal seams and there is a greater amount of uncertainty associated with their amenability to CO<sub>2</sub> storage. Saline formations have been used for storage of chemical waste in a few cases; their main advantages are: a large potential storage volume and common occurrence, and large geographical extent.

### TERRESTRIAL ECOSYSTEMS

Terrestrial sequestration is the enhancement of CO<sub>2</sub> uptake by plants that grow on land and in fresh water and in soils where it may remain more permanently stored. Terrestrial sequestration provides an opportunity for low-cost CO<sub>2</sub> emissions offsets. Early efforts include tree-plantings, no-till farming and forest preservation. More advanced research is being conducted to develop fast-growing trees and grasses, and decipher the genomes of carbon-storing soil microbes. The scope of terrestrial sequestration options addressed is limited to the integration of energy production, conversion, and use with land reclamation. Specifically, this involves reforestation and amendment of mined lands and other damaged soils, when possible, using solid residuals from coal combustion.