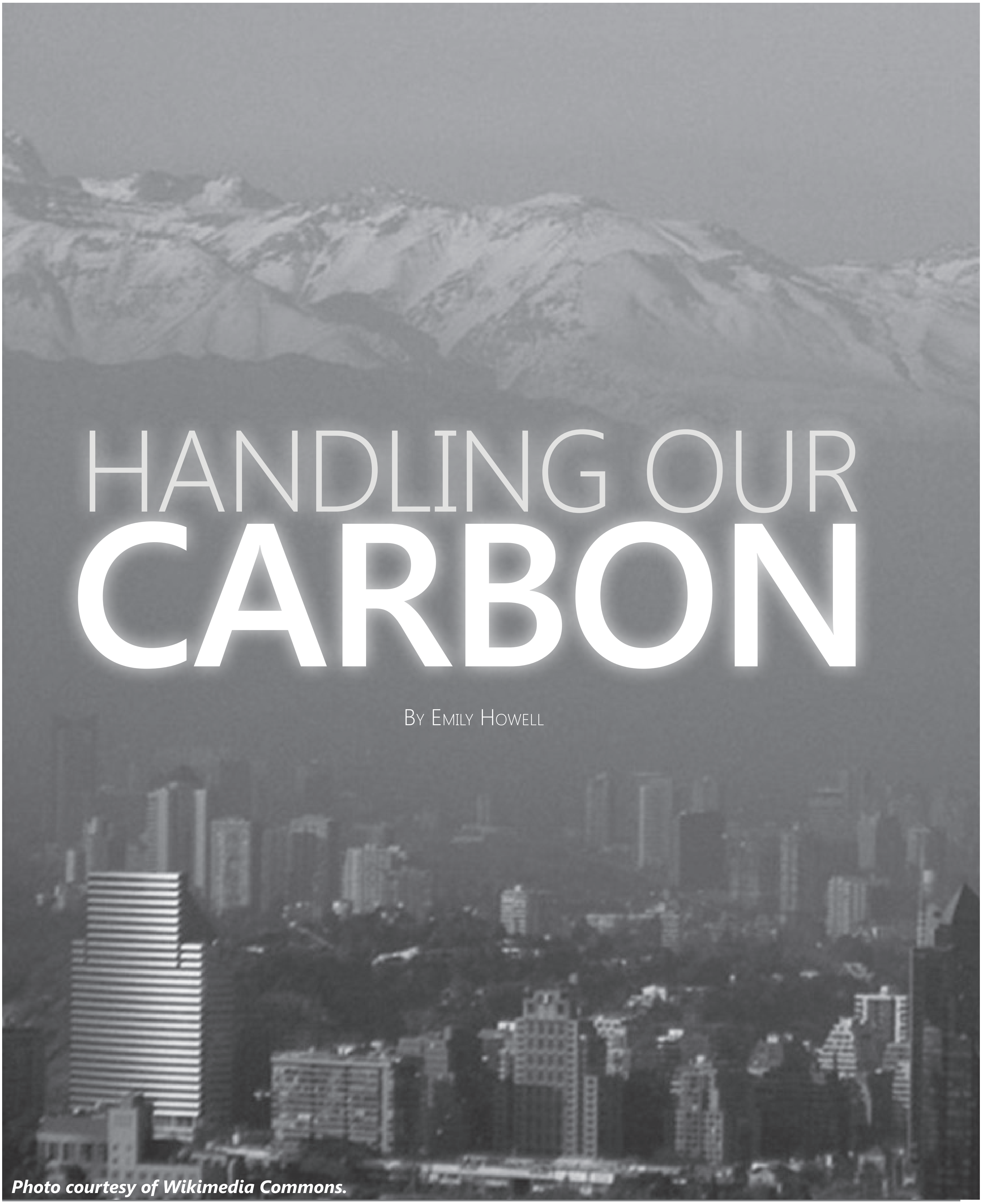


HANDLING OUR CARBON

By Emily Howell

Photo courtesy of Wikimedia Commons.

After a long history of American presidents focusing little attention on climate change, President Barack Obama clearly established that halting the acceleration of human-driven climate change is one of his priorities for his last term. In his post-election acceptance speech, inaugural address, and 2013 State of the Union address, the President highlighted climate change and alternative energy sources, as well as the urgency of putting effective policy into place to stabilize current climate change. While some "may still deny the overwhelming judgment of science," he stated in his inaugural address, "none can avoid the devastating impact of raging fires and crippling drought, and more powerful storms"(1).

Though he has become more vocal during this term about the need to address greenhouse gas emissions, the President had actually been taking steps to tackle the issue since his first term. In February 2010, President Obama created the Interagency Task Force on Carbon Capture and Storage (CCS) and charged it with researching and developing a strategy for using CCS to reduce greenhouse gas emissions from major fossil fuel energy sources. Five years earlier, President George W. Bush had also delegated government efforts towards research and development of CCS technology, when the Environmental Protection Agency (EPA) and the Department of Energy (DOE) became involved in CCS projects in 2005. So even in the highly politicized issue of addressing climate change, CCS has received support from Republican and Democratic administrations over the past decade, yet it has remained surprisingly low on the public radar. This lack of widespread knowledge begs the question: What is CCS, and what are we, through federal policy and funds, supporting?

The Technology of Capture and Sequestration

Carbon capture and sequestration, or storage, involves a three-step process of capturing carbon dioxide emissions from industrial fossil-fuel-burning power plants, compressing and transporting the emissions, and injecting them into porous rocks more than a mile underground. The first step – capture -- can be done in one of three ways: pre-combustion, post-combustion, or oxy-combustion. Pre-combustion simply means separating the CO_2 through gasification, or turning coal into a gas before it is burned, and converting the resulting carbon monoxide into CO_2 that is then filtered out (2). Because this process requires advanced technology that is still emerging, it is not widely used.

Post-combustion is the most common and compatible method because it involves streaming exhaust gases from the burned coal through a material that absorbs most of the CO_2, which can be accomplished by replacing smokestacks with new absorption towers at existing coal-burning plants to isolate the CO_2 from the other exhaust gases (2, 3).

Oxy-combustion is the most efficient of the methods, but also the most expensive for retrofitting existing power plants. It requires burning the coal in pure oxygen, rather than air, producing an exhaust gas that is primarily water and CO_2. The water vapor is then condensed, leaving only the CO_2 in gas form, which makes it easier to pipe the CO_2 away for compression and transport. Although expensive, if made more economical to implement, oxy-combustion would reduce the long-term cost of capture (2).

The captured carbon is then compressed for transport to the sequestration site. Pipelines are the primary form of transportation, but the pressurized CO_2 can also travel by train, truck, or ship. Once transported, the carbon is then injected deep into solid but porous rocks – like sandstone or shale - at high enough pressure and temperature that it becomes a "supercritical fluid" that is able to diffuse easily through porous spaces like a gas can, but takes up less space, like a liquid. Depths of 2,600 feet or greater are needed to keep the CO_2 in a supercritical state and prevent it from leaking through as a gas.

Secure storage requires a "cap rock" on top of the rock layers to prevent the pressurized carbon from escaping. Injecting the CO_2 into depleted oil fields is the most common method of sequestration as it also aids in removing leftover oil. The CO_2 reduces friction between the oil and the rock, increasing the oil flow out of the reservoir (2). This "enhanced oil recovery" (EOR) is one of the primary uses of captured CO_2 today, but if the projected trillions of tons of carbons are going to be stored over the next century, larger reservoirs will be required than the oil fields offer (4).

Researchers are exploring many options that could provide enormous storage potential, such as sedimentary brine formations, or porous rocks containing salt water deep under the ocean (2). While it is not clear if these formations will be secure enough, some have been identified as being able to store over 450 years of CO_2 emissions, assuming current emission rates (5). Hypothetically, engineers could also find a way to mimic the natural carbon sink provided by the ocean and turn carbon

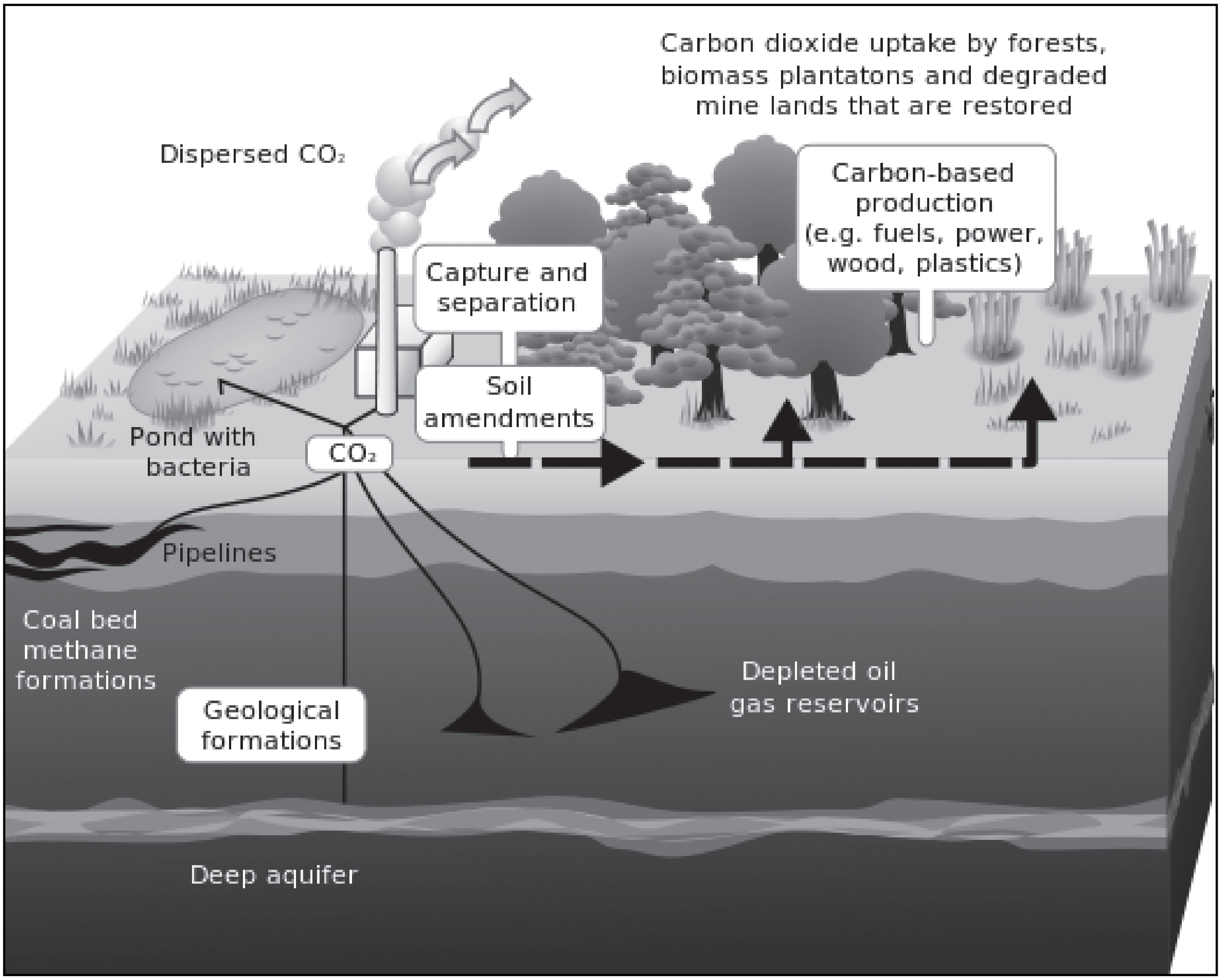


Figure 1: Schematic showing geological sequestration of carbon dioxide emissions from a coal-fired plant. Rendering by LeJean Hardin and Jamie Payne. ***Photo courtesy of Wikimedia Commons.***

dioxide into limestone (2). Basalt formations, or volcanic rocks like those formed by the lava flows in Hawaii, could potentially store the CO_2 as well, by chemically absorbing it through mineralization (5).

The State of CCS Today

Since 2005, 500 million tons of CO_2 emissions have been sequestered underground , and the American government has increased support for the development and implementation of CCS technologies. The DOE, using funds from the American Recovery and Reinvestment Act, is currently supporting demonstration projects in different power plants to show the effectiveness of CCS (3), and it is actively involved in research and development through its National Energy Technology Laboratory (NETL) (5). The federal government also provides tax credits for private companies that choose to invest in CCS-equipped plants, and the Environmental Protection Agency ensures that storage is done in safe and environmentally considerate ways (4).

CCS is particularly attractive for reducing the effects of anthropogenic greenhouse gases because it allows the use of coal and oil for generating energy without accelerating climate change. In the U.S., more than 40 percent of CO_2 emissions are from electric power generation (4), and we depend on those coal-fired plants to produce 40 to 45 percent of the nation's energy (3). On a global scale, coal is the preferred fuel for generating electricity, especially in quickly growing China and India (6), and fossil fuels are still considered the "most-dependable, cost-effective energy sources in the world," despite the long-term damage fossil fuels create through climate change (5).

Equipping power plants with CCS technologies can reduce CO_2 emissions by 80 to 90 percent without drastically changing the dominant energy production system (4, 7). A reduction of 80 to 90 percent, according the EPA, is equivalent to planting more than 62 million trees to absorb atmospheric CO_2 and waiting ten years for them to grow -- or to cutting out annual electricity-related emissions from more than 300,000 homes (4). The DOE estimates that anywhere from 1,800 to 20,000 billion metric tons of CO_2 could be stored underground, which translates into 600-6,700 years of current level emissions from large stationary sources in the U.S. (4).

The captured carbon can also be used by other industries. As seen with EOR, oil companies have an incentive to use the carbon injections to remove leftover oil from wells, and in 2011, 88 percent of captured CO_2 was used for EOR (2). The captured carbon is also used by food and beverage producers to create carbonation in soft drinks or manufacture dry ice (2).

Because of these benefits, over 120 facilities in the U.S. currently use CCS technologies, and interest is increasing. The Obama administration is developing six demonstration projects that will likely be completed by 2016 (3, 6). The DOE recently announced the beginning of Phase II of its CCS project, building a large CCS technology-equipped power plant in Illinois with the non-profit organization FutureGen Industrial Alliance, which strives for near zero-emission coal technology. The plant will use the more efficient oxy-combustion technology and is projected to be capable of capturing 1 million tons of CO_2 a year, or more 90 percent of the plant's emissions (8).

Pressures in the Pipeline – The future of CCS

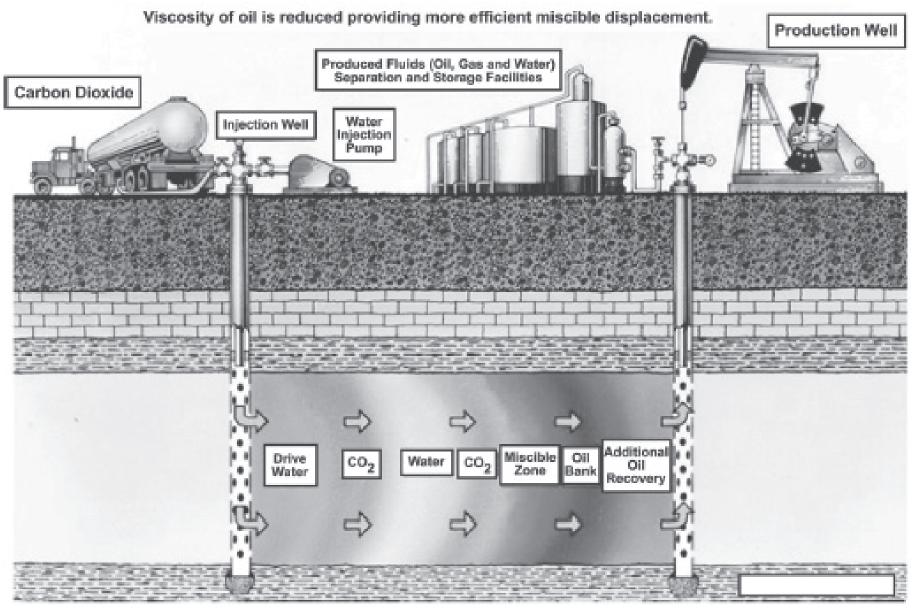
Still, CCS raises concerns from the scientific, technical, and political side. Especially since the general public knows little about the details of CCS, public approval is one of the largest concerns. A tri-annual survey by the MIT Carbon Capture and Sequestration Technologies Program, one of the international leaders in CCS research, found that only 17 percent of people polled recognized the term "carbon capture and sequestration." While this marked an increase from only 5 percent in 2006, those who recognized CCS did not fully accept it as a viable option for addressing climate change. When asked if they would include CCS in a climate change plan, 25 percent responded favorably, 25 percent were opposed, and 50 percent were unsure (9). Because people are unfamiliar with the details of the process, they remain uncertain about what environmental or other safety issues it could raise. Some of the more common concerns are that the pressure from sequestered CO_2 deep underground could cause earthquakes or pollute the aquifers. As science fiction-like as it may seem, sequestered CO_2 could indeed cause minor seismic events. However, the EPA states that sequestration sites are chosen in seismically stable, non-volcanic regions, and that the pressure-build up from injections could only trigger seismic movements too small to be noticed (4). As for drinking water, the Agency states that it ensures that sequestration sites do not have improperly drilled holes, faults or rock fractures that could allow leaks into drinking water (4).

Some are also concerned that CCS is a distraction from sustainable energy technology developments and implementation. On the other hand, the MIT Program sees CCS as a complement to other energy-development projects, not as a replacement. Along with the NETL, they contend that CCS, combined with improved energy efficiency and increased use of non-carbon energy sources, will be needed in order to stabilize greenhouse gas concentrations(5, 7). The NETL argues that switching from fossil fuels will take time, during which industries will continue to emit large volumes of CO_2. To paraphrase, in their view using CCS is akin to using buckets to remove water from a pool in danger of overflowing (5).

Yet, concern of CCS distracting from the development of alternative energy sources, however, may be valid, as the biggest issue raised about CCS is the large amount of money necessary to make it feasible and attractive to industries. Since 2005, Congress has allocated $6.9 billion to the DOE to further develop CCS technology, but it remains unclear whether CCS will be economically sustainable, even after these funds have created CCS-equipped plants (3). Engineers estimate that electricity generated by CCS-equipped plants would be 75 percent more costly than that generated by conventional coal-fired plants, largely because of the extra facilities and energy needed to capture CO_2 . Plus, the extra energy required means that the overall energy available for sale is reduced by 15 to 30 percent, so plants need to be larger in order to serve the same number of customers (3). Additionally, demands for electricity are increasing. Although better technology could bring the cost down over time, the Congressional Budget Office found that, "in absence of a significant technological breakthrough," taxes on CO_2 emissions or policies restricting CO_2 emissions will be required to allow coal-fired plants with CCS to be competitive with those lacking the technology (3). According to the CBO, current policies are unlikely to make that possible. Instead, reallocating funds from large demonstration projects to more research and development for improving the technology or to the implementation of a cap-and-trade policy could be more effective at making CCS economically viable (3, 6). Unless lawmakers "substantially increased support for CCS," the Budget Office found that "federal funding would be likely to contribute only a little to reducing the costs of CCS-equipped coal plants" (3). At the same time, private industries are unlikely to invest in such an expensive technological system without provided incentives (3).

In more optimistic news for CCS advocates, many engineers believe that the "prospect for success" in solving the problems of capture and storage "appears high." In a 2007 article in Science, Harvard geoscientist Daniel Schrag wrote that no scientific or economic challenge exists that is "serious enough to suggest that [CCS] will not work at the scale required to offset trillions of carbon dioxide emissions over the next century"(10), and the National Academy of Engineering has assigned "develop carbon sequestration methods" as one of its "Grand Challenges for Engineering," encouraging current and future engineers to take on the goal of advancing CCS technologies (2). Although the use of stored carbon for EOR is still seen as a "promising route," the state of CCS is far from stable in the U.S. (6). While it could offer great potential in curbing CO_2 emissions, the future success of CCS will depend on whether the American public and lawmakers view it as a development worth supporting and financing.

Figure 2: Enhanced Oil Recovery: Illustration of an injection well in an oil reservoir in which sequestered CO2 can aid in oil recovery. ***Photo Courtesy of Department of Energy National Energy Technology Laboratory.***



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