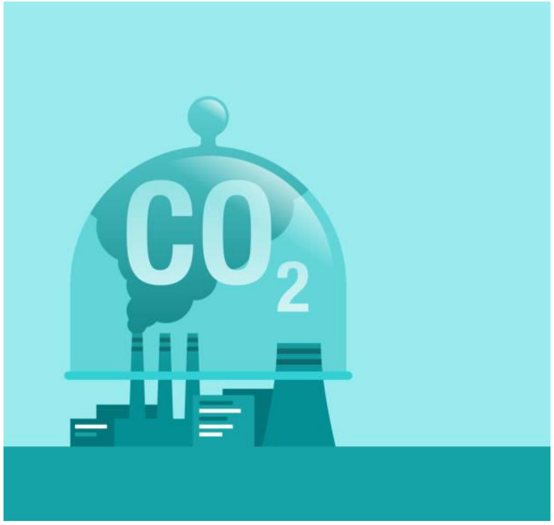

MAX NetZero™

Carbon Capture & Sequestration
CCS

Vortex Energy Group LLC
www.VortexEnergyGroup.com

CONCEPT DOCUMENT

Carbon Capture & Storage aka Carbon Sequestration:

Collection and Reuse of Carbon Dioxide (CO_2) Emissions

By Jim VanNatta
Founder / CEO
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www.VortexEnergyGroup.com

Contents

Did you know?...

…That CO_2 can be reused to help plants grow better in greenhouses?

Introduction

The purpose of these Concept Documents is to raise awareness of exciting technologies that are available, but not properly implemented. We are hoping to stimulate the conversation, so that we can encourage some of the brightest minds in this country to consider the potential in what these concepts offer.

Working in association with the contacts we have through our ***3e Research Alliance*** *SM*, we plan to engage subject matter experts, and discover new approaches to existing methods. In our previous discussions, we have urged a “back-to-basics” approach to looking at these critical issues that we face today.

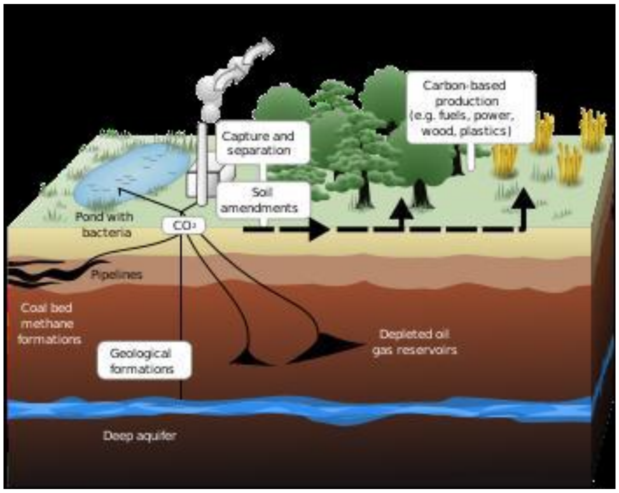
Using that as a backdrop, this latest concept, carbon capture and storage (CCS), also known as carbon sequestration, is an exciting and promising technology that is literally on the edge of discovery. We will describe the history and background, as well as offer details on what hurdles have arisen. This is a very exciting concept, and one that we want to encourage people to embrace, no matter which end of the environmental debate you are on.

Background

As is the case with any technology, there are portions of CCS that come from decades of related ideas, and put together with a new focus towards current needs and issues. This is similar to our own vortex technology, in that we have embraced the core technology, and added new features that were not available prior, but that enhance the efficiency without altering the original process.

CCS is a relatively new concept, having its origins as recent as only 15 years ago, and with major breakthroughs in 2008 and 2009. These were systems installed at power plants, which are the best resource for this type of process. In most cases, these facilities are large power-producing sites, creating a new set of issues.

As you can see in the image below, the carbon process can include what is known as terrestrial and geological separation of CO_2 emissions, in this case, from a coal-fired plant.



The problem with this type of facility is that the capture and compression of the CO_2 requires more energy, and would increase the fuel needs of the plant. Those costs would then increase the cost of the power to the consumer. For that reason, there has been limited interest in this type of addition to existing sites.

Our Method

Something that we have as an advantage is our size. We are a base-load power generation technology, but with an extremely small footprint. Most power plants that generate at least 6 megawatts or more, have a larger footprint, which requires specific methods for capturing and storing the CO_2. We are very fortunate, due to our overall design and technology, in that we are able to take advantage of other methods that don't require such large uses of power, and are relatively low cost.

Specifically, we will use a compound named monoethanolamine (MEA). In stoichiometric combustion systems - those with complete combustion such as our vortex unit, the two by-products are CO_2 and water. This process condenses the water vapor through cooling it, leaving the CO_2 to be collected.

However, in our CCS method, we will pass the emissions from our vortex unit through the MEA (which is a viscous liquid material), which "collects" the CO_2. As the MEA is later boiled, it gives off the CO_2 which is collected and stored. In essence, it's like creating a still for capturing the CO_2 gas.

Removing CO_2 from exhaust is also known as scrubbing. There are many types of exhaust scrubbers available, utilizing various methods where the CO_2 is absorbed into some type of solution, and transferred to lime through a process called causticization, then released into a kiln. An alternative method to this thermo-chemical process uses electrical charges to release the CO_2.

Over the past three or four years, amine scrubbing has become the dominant method of removing CO_2 from the exhaust of coal-fired and gas-fired power plants. With the larger sites, this has also become a financial issue, and progress has been limited. Again, that is where our technology will offer a small, low cost process whereby we can pass the exhaust through the MEA, and then later capture it from the release of the heated compound, making it ready for storage and re-purposing.

Our Efforts

While we have been fortunate to work with some of the industry's leading experts on MEA and other scrubbing technologies, we are currently developing new R&D efforts to find more efficient, cost saving methods to clean all exhaust gases from various existing systems. We believe that it will be impossible to totally replace all waste-to-energy (WtE) technologies that use combustion, so it's our goal to at least find a means to be able to clean up those flue gases, making conventional systems compliant with current environmental requirements.

As we touched on earlier, we are using our contacts and connections with research groups through various universities and colleges around the country, to implement a unique process for research and development. As part of an ongoing program, we are establishing an alliance comprised of some of our top minds from various universities, governmental agencies, as well as innovators and entrepreneurs that can provide valuable resources. The purpose and goal is to once and for all develop or enhance technologies that can make a ***real*** difference in how we provide environmentally safe energy while also strengthening our economy.

In addition to developing our CCS systems, we are also wanting to focus on removing sulfur from flue gases, known as desulfurization. While our technology prevents the production of harmful emissions, some waste materials, such as waste coal, formerly known as dirty coal, contains much higher levels of sulfur, making this material impossible to use in conventional coal-fired furnaces. With our design, we virtually eliminate all SO_2, or sulfur dioxide, reducing it to a level that is required by current EPA standards and regulations.

However, our goal is to totally eliminate all harmful emissions from this process, and our initial research has uncovered currently unused methods for scrubbing those remaining elements. We are currently working with experts in crowdfunding to initiate a campaign to raise funds to assist us with our R&D efforts.

In Summary

Although our technology offers very clean emissions, there is still concern by some in terms of any CO_2 being released into the atmosphere. While that is best left for another forum, we are open to any idea that can help to make this process more efficient, and still take away any perception of possible harm to the environment. Public acceptance is always important to gain wide spread use of any technology or program, so we welcome all points of view, particularly those that will not interrupt the opportunity to make a real difference in environmental energy programs in this country.

Carbon capture and storage is a very young concept, and one that we hope will expand in use. Combining this technology with our micro power generation, we are confident that a solution that will be embraced by all will emerge.

Over the past years, we have been proposing two simple steps that will ensure that our energy programs are addressed properly:

1. Allow for fast-tracking of all issues related to alternative or renewable energy programs, such as permits, legislation, funding, and more. This will ensure that these critical issues no longer get bogged down in the mess of bureaucratic red tape.

2. We also propose that alternative energy programs be given the same tax benefits that are currently only provided to renewable energy. This will encourage new technologies to emerge or be discovered, that could make a real difference in our desire for:

Energy Independence
Economic Strength
Environmental Security

Contact Us

For more information about these concepts, our ***Thermo*MAX™** Series Thermal Vortex System, or any of our programs such as our legislative efforts, please contact us at the following:

By phone: 317-512-6951
By email: Info@VortexEnergyGroup.com
Online: www.VortexEnergyGroup.com

Process description of using MEA to capture CO2

Monoethanolamine (MEA) is a widely used chemical for capturing CO_2 from industrial exhaust streams due to its strong affinity for CO_2 and the ease of regenerating the chemical. Below is a detailed process of how MEA can be employed to capture CO_2 from the exhaust stream of a thermal vortex chamber operating at 90 mph with an exhaust temperature of 2,000°F.

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1. Cooling the Exhaust Stream

The first step is to cool the exhaust gases to a temperature suitable for the MEA-based absorption process:

- **Cooling Mechanism**: High-temperature exhaust gases (~2,000°F) would destroy MEA and degrade the process efficiency. The gas is cooled using a heat exchanger or quenching system that reduces the temperature to below 150°F, typically to the 100–140°F range.
- **Heat Recovery**: The excess heat can be recovered during cooling to improve overall system efficiency, potentially preheating incoming air or powering auxiliary equipment.

---

2. Dust and Particulate Removal

- **Pre-scrubbing**: A particulate scrubber or electrostatic precipitator is used to remove soot, ash, and dust from the gas stream, preventing MEA contamination.
- **Acid Gas Removal**: If present, sulfur oxides (SO_x) and nitrogen oxides (NO_x) are neutralized or reduced to avoid MEA degradation.

---

3. Absorption in the MEA Solution

- **Absorption Tower Design**: The cooled and cleaned exhaust stream is passed through an absorption tower packed with structured packing or trays to maximize gas-liquid contact.
- **Chemical Reaction**:
    - CO_2 reacts with MEA in the aqueous solution to form a stable carbamate compound: CO2+2 MEA→MEA−COO−+MEAH+CO_2 + 2 \, MEA \ → MEA-COO$^-$ + MEAH$^+$CO2+2MEA→MEA−COO−+MEAH+
    - This reaction is exothermic and effectively captures CO_2 from the gas phase.
- **Efficiency**: The CO_2 absorption efficiency depends on the MEA concentration (typically 20–30% by weight), gas flow rate, and contact time.

---

4. Stripping and Regeneration of MEA

- **Regeneration Tower**: The CO_2-laden MEA solution is pumped to a stripping column or regenerator.
- **Heat Application**: Heat is applied (typically using steam) to reverse the chemical reaction, releasing pure CO_2 gas: MEA−COO−+MEAH+→CO2+2 MEAMEA-COO^- + $MEAH^+$ \ → CO_2 + 2 \, MEAMEA−COO−+MEAH+→CO2+2MEA
- **MEA Recovery**: The regenerated MEA is recycled back to the absorption column.

---

5. CO_2 Compression and Storage

- **Compression**: The released CO_2 is compressed for transportation or storage.
- **Utilization/Sequestration**: The CO_2 can be:
  - Injected into geological formations for long-term sequestration.
  - Used in enhanced oil recovery (EOR) or industrial processes like carbonation or synthetic fuel production.

---

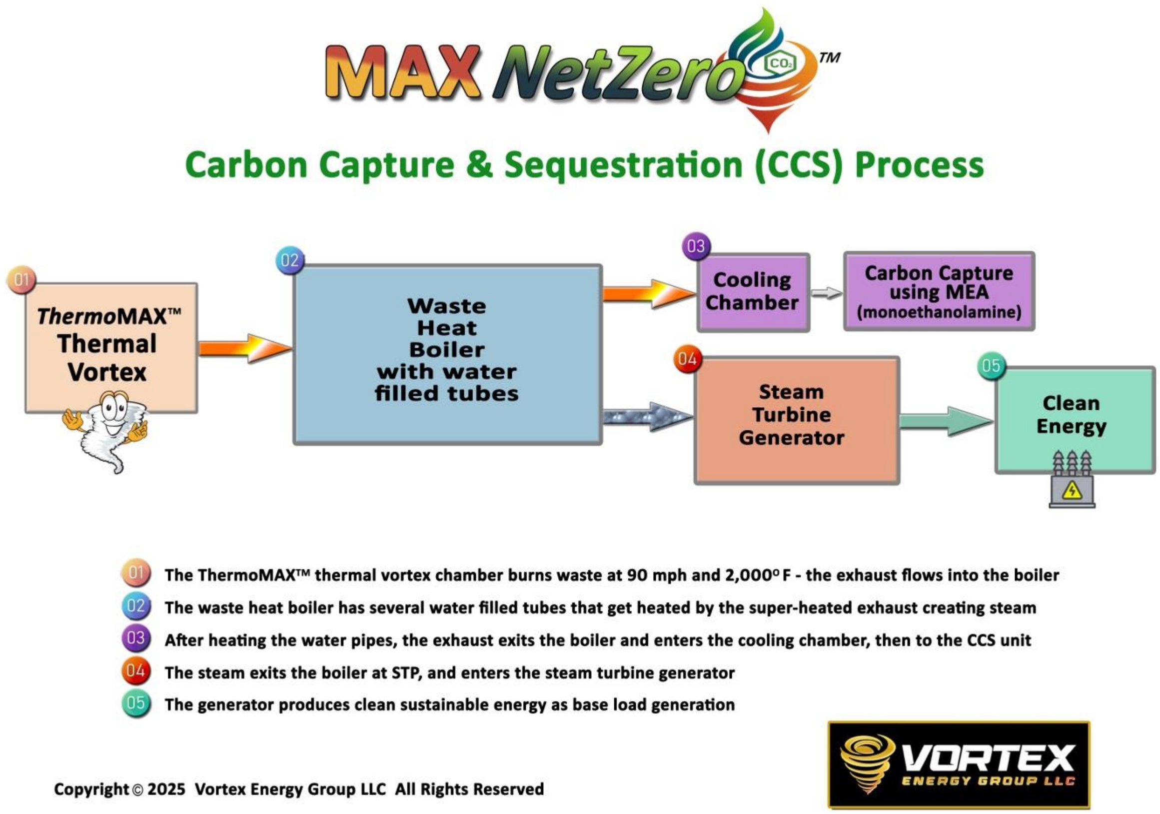
6. Additional Considerations

- **High Gas Velocity (90 mph)**:
  - The high velocity poses challenges for effective gas-liquid contact. Flow dynamics and turbulence must be managed using tailored tower designs and optimized packing.
- **Material Selection**:
  - The system must use corrosion-resistant materials since MEA is corrosive, especially in the presence of contaminants like oxygen or sulfur.
- **MEA Degradation**:
  - Periodic replacement or purification of the MEA solution is necessary to address thermal or oxidative degradation.

Innovations and Challenges

- **Energy Optimization**: The energy-intensive nature of MEA regeneration requires energy recovery systems to ensure cost-effectiveness.
- **Alternative Amine Blends**: Blends of MEA with other amines or additives can improve CO_2 capture efficiency and reduce degradation.
- **System Integration**: The CO_2 capture unit must be seamlessly integrated with the thermal vortex chamber to minimize pressure drops and ensure operational stability.

This approach represents a highly engineered solution to capture CO_2 efficiently while managing the challenges posed by high velocity and temperature exhaust streams.

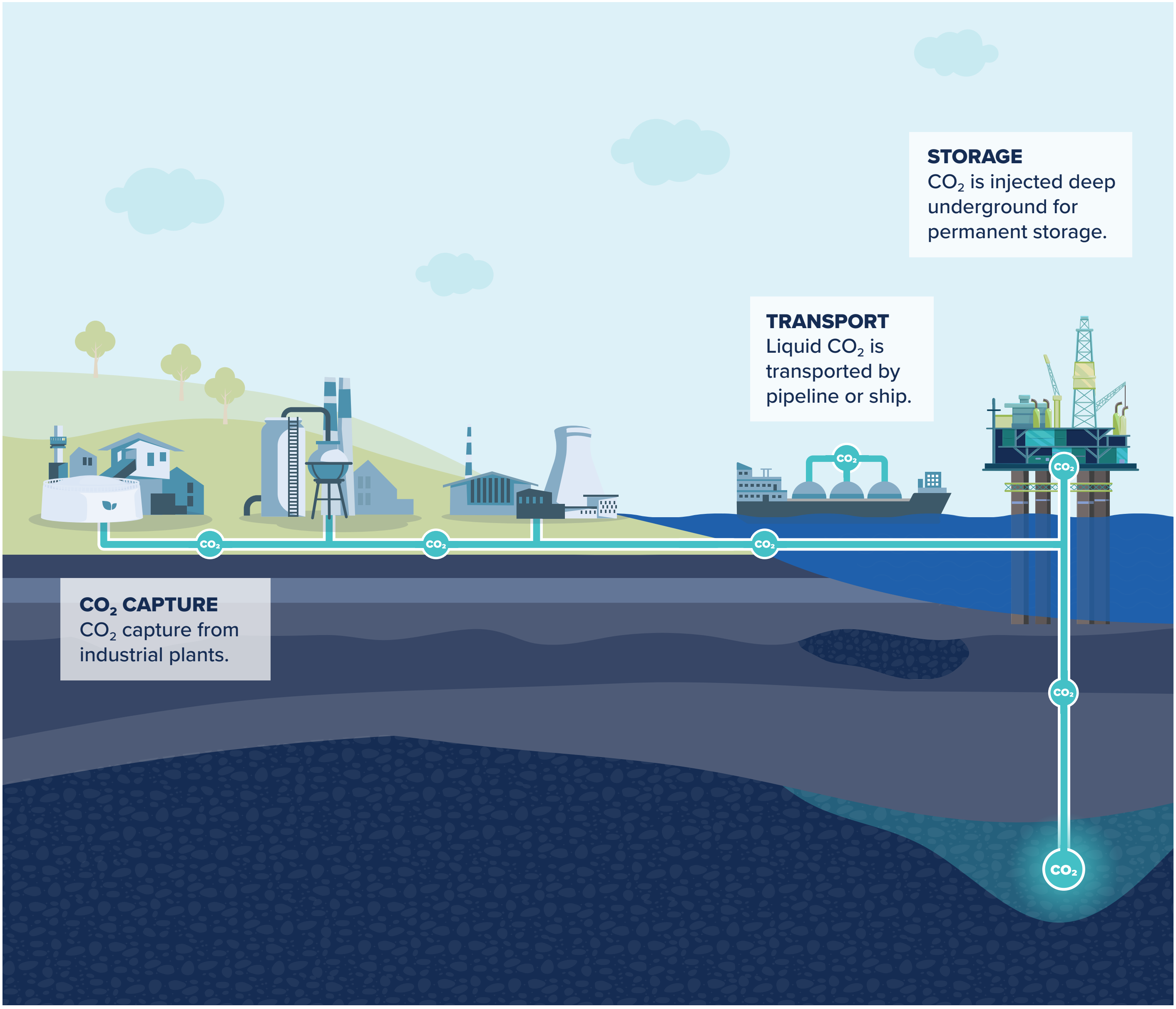


WHAT IS CCS?

“Carbon Capture and Storage” or “CCS” is a term that refers to technologies that capture the greenhouse gas carbon dioxide (CO_2) and store it safely underground, so that it does not contribute to climate change. CCS includes both capturing CO_2 from large emission sources (referred to as point-source capture) and also directly from the atmosphere.

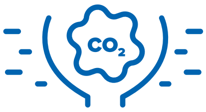
Point-source capture is when a large emission source, like an industrial facility, is equipped with technology allowing the capture and diversion to storage of CO_2, preventing it from being emitted. It is also possible to remove historical CO_2 emissions, those that are already in the atmosphere, through direct air capture and storage (DACCS) or bioenergy with capture and storage (BECCS).

CCS can be applied across sectors vital to our economy, including cement, steel, fertilisers, power generation and natural gas processing, and can be used in the production of clean hydrogen.



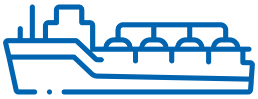
HOW DOES IT WORK?

Carbon capture and storage involves three steps – capture, transport and storage.



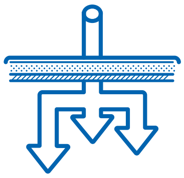
CAPTURE

During capture, CO_2 is separated from other gases produced at large industrial facilities, such as steel mills, cement plants, petrochemical facilities, coal, and gas power plants, or from the atmosphere. There are several capture methods in use – all are proven and effective, with different methods applied based on the emissions source.



TRANSPORT

Once separated, the CO_2 is compressed for transportation. This means increasing pressure so that the CO_2 behaves like a liquid. The compressed CO_2 is then dehydrated before being sent to the transport system. Pipelines are the most common mode of transport for large quantities of CO_2. For some regions of the world, CO_2 transport by ship is an alternative.



STORAGE

Following transport, the CO_2 is injected into deep underground rock formations, often at depths of one kilometre or more, where it is safely and permanently stored. These rock formations are similar to what has held oil and gas underground for millions of years. Close to 300 million tonnes of CO_2 has already been safely and successfully injected underground. Fortunately, there is an abundance of storage available around the world.

WHY IS CCS NECESSARY?

Climate change is the most urgent challenge facing humanity today, and the science is clear that we must use every tool at our disposal if we wish to avoid the worst of its impacts. The world's leading climate and energy bodies - the United Nations' Intergovernmental Panel on Climate Change (IPCC) and the International Energy Agency (IEA) – have both outlined a clear and important role for CCS in reaching net-zero emissions by 2050. Moreover, experts agree that CCS will be particularly vital for hard-to-abate sectors like cement and steel production, where no other viable solutions currently exist, and for removing CO_2 already in the atmosphere.

Simply put, we are running out of time to reduce our global emissions and it is becoming increasingly clear that any realistic path forward on climate action will include CCS.

CCS is already happening around the world. There are currently 29 operating facilities with a cumulative capture capacity of nearly 40 million tonnes per annum, the equivalent of taking nearly 8 million cars off the road.

There are now over 100 facilities across all stages of development and across a range of sectors, but much more needs to be done.

United States
Environmental Protection
Agency

Carbon Dioxide Capture and Sequestration: Overview

Featured Topics

- Federal Research and Regulations

What is carbon dioxide capture and sequestration?

Carbon dioxide (CO_2) capture and sequestration (CCS) is a set of technologies that can greatly reduce CO_2 emissions from new and existing coal- and gas-fired power plants and large industrial sources. CCS is a three-step process that includes:

- Capture of CO_2 from power plants or industrial processes
- Transport of the captured and compressed CO_2 (usually in pipelines).
- Underground injection and geologic sequestration (also referred to as storage) of the CO_2 into deep underground rock formations. These formations are often a mile or more beneath the surface and consist of porous rock that holds the CO_2. Overlying these formations are impermeable, non-porous layers of rock that trap the CO_2 and prevent it from migrating upward.

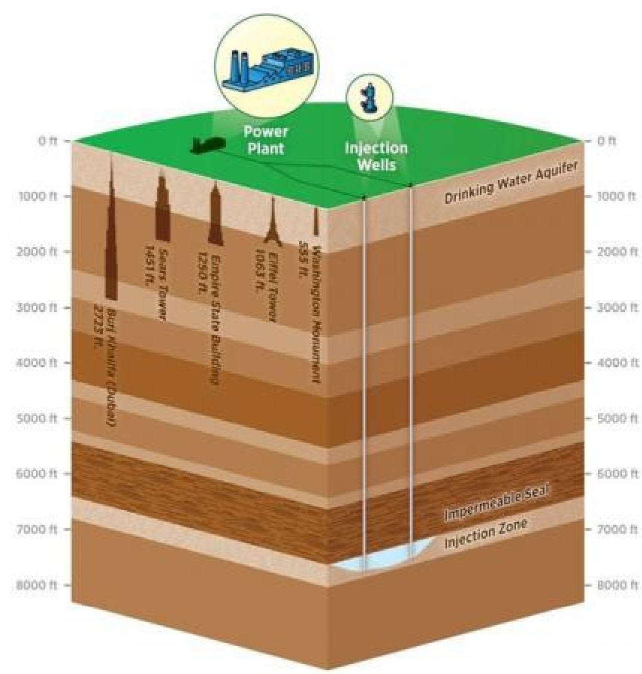
Quick Fact

What's the difference between carbon dioxide capture and sequestration (CCS) and geologic sequestration?

Geologic sequestration is one step in the CCS process. Unlike terrestrial, or biologic, sequestration, where carbon is stored via agricultural and forestry practices, geologic sequestration involves injecting carbon dioxide deep underground where it stays permanently.

The figure to the right5 illustrates the general CCS process and shows a typical depth at which CO_2 would be injected.

CCS Schematic (Subsurface depth to scale, 5,280 feet equals one mile)



Why is it important?

Learn More

EPA's Greenhouse Gas Reporting Program (GHGRP) collects information from facilities in 41 industry types that directly emit large quantities of GHGs, suppliers of certain fossil fuels, and facilities that inject CO_2 underground.

Carbon dioxide (CO_2) capture and sequestration (CCS) could play an important role in reducing greenhouse gas emissions, while enabling low-carbon electricity generation from power plants. As estimated in the *U.S. Inventory of Greenhouse Gas Emissions and Sinks*, more than 40% of CO_2 emissions in the United States are from electric power generation. CCS technologies are currently available and can dramatically reduce (by 80-90%) CO_2 emissions from power plants that burn fossil fuels. Applied to a 500 MW coal-fired power plant, which emits roughly 3 million tons of CO_2 per year,[1] the amount of GHG emissions avoided (with a 90% reduction efficiency) would be equivalent to:

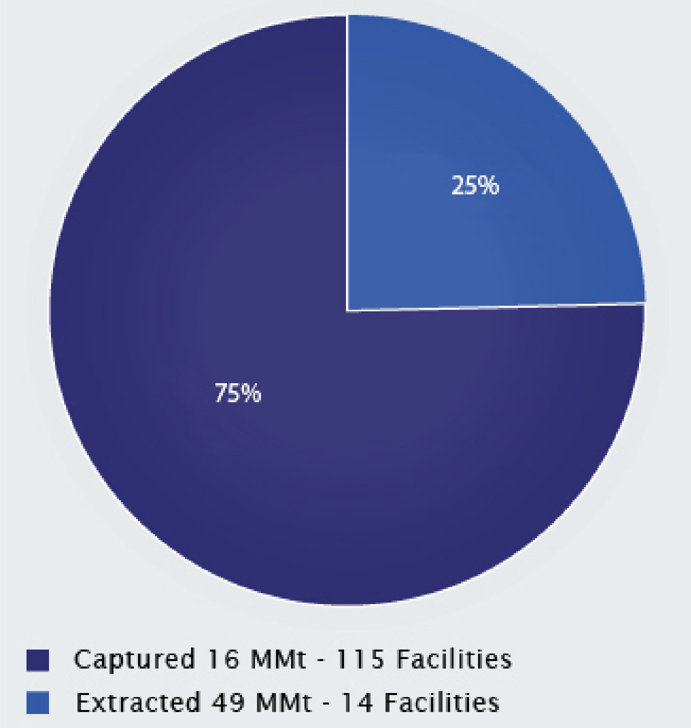
- Planting more than 62 million trees, and waiting at least 10 years for them to grow.
- Avoiding annual electricity-related emissions from more than 300,000 homes.

To see this emissions reduction expressed in other equivalent terms, see EPA's Carbon Equivalencies Calculator.
CCS could also viably be used to reduce emissions from industrial process such as cement production and natural gas processing facilities.

What sources of carbon dioxide can it be applied to?

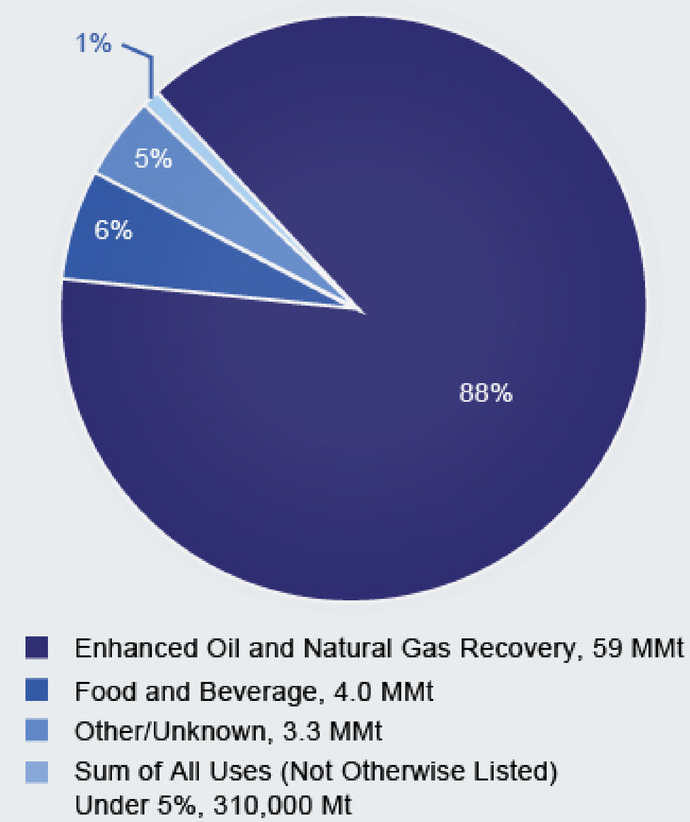
Carbon dioxide (CO_2) capture and sequestration (CCS) can significantly reduce emissions from large stationary sources of CO_2, which include coal- and natural-gas-fired power plants, as well as certain industry types such as ethanol and natural gas processing plants. EPA's Greenhouse Gas Reporting Program includes facilities that capture CO_2 for the purpose of supplying the CO_2 to the economy or for injecting it underground (Subpart PP). According to the Greenhouse Gas Reporting Program, CO_2 capture is currently occurring at over 120 facilities in the United States, mainly on industrial processes, and the CO_2 is used for a wide range of end uses. End uses of CO_2 include enhanced oil recovery (EOR), food and beverage manufacturing, pulp and paper manufacturing, and metal fabrication. The figure below shows the portion of CO_2 that is currently being captured from power plants and other industrial facilities and the portion that is extracted by production wells from natural CO_2 bearing formations in the United States. The second figure shows the various domestic end uses of captured and extracted CO_2. (Note that natural sources of CO_2 are not considered in the Total CO_2 Supply End Uses figure). As CCS becomes more widespread, it is expected that the portion of CO_2 captured in the United States from power generation and industrial processes will increase.

Capture and Extraction Facilities CO_2 Supplied in 2011



* Source: EPA Greenhouse Gas Reporting Data – Subpart PP – Suppliers of Carbon Dioxide. Based on 2011 data. MMT = million metric tons

Capture and Extraction Facilities CO_2 Supplied to End Uses in 2011



* Source: EPA Greenhouse Gas Reporting Data – Subpart PP – Suppliers of Carbon Dioxide. Based on 2011 data. MMT = million metric tons

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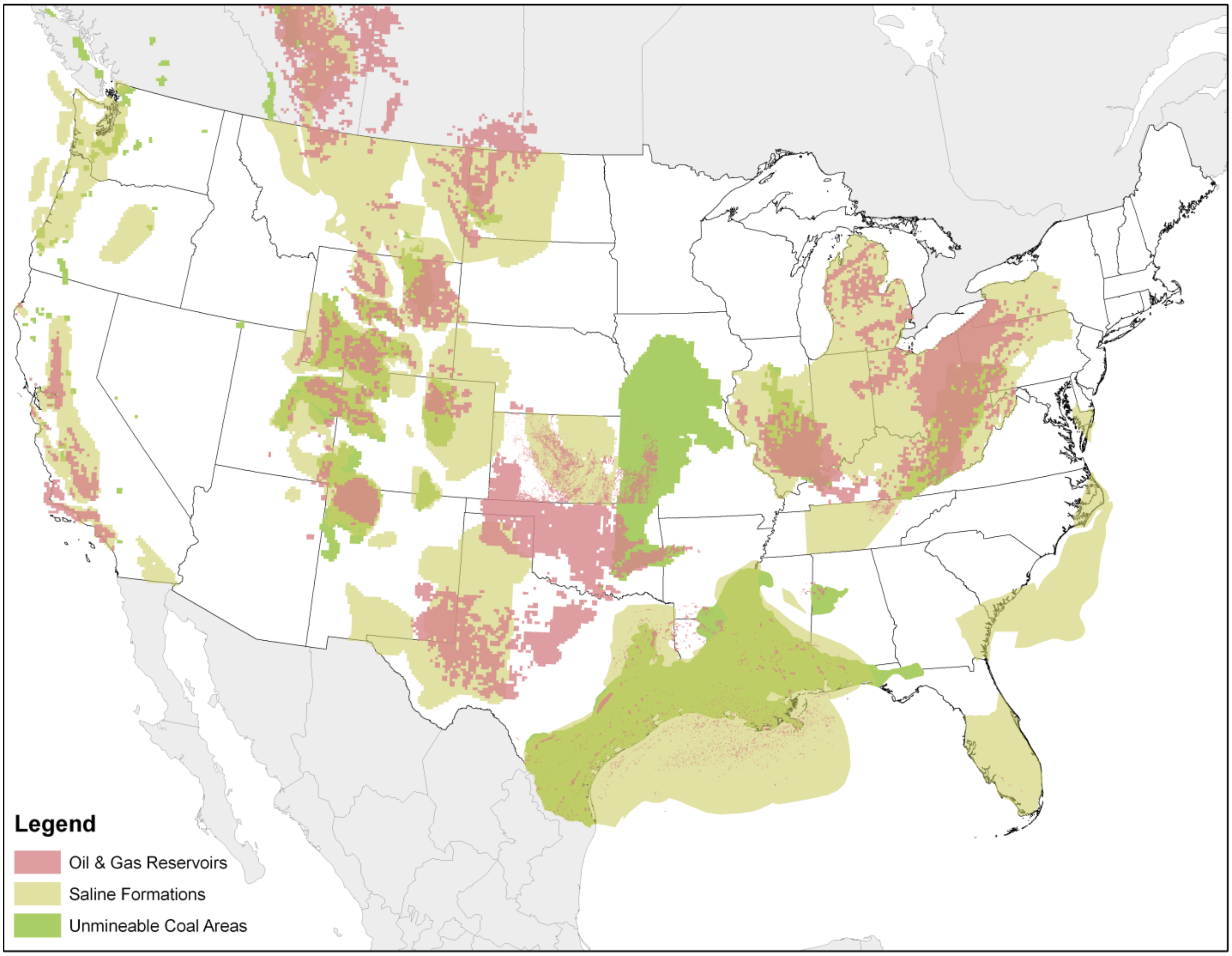
Where can captured carbon dioxide be stored?

After capture, carbon dioxide (CO_2) is compressed and then transported to a site where it is injected underground for permanent storage (also known as "sequestration"). CO_2 is commonly transported by pipeline, but it can also be transported by train, truck, or ship. Geologic formations suitable for sequestration include depleted oil and gas fields, deep coal seams, and saline formations. The U.S. Department of Energy estimates that anywhere from 1,800 to 20,000 billion metric tons of CO_2 could be stored underground in the United States.[2] That is equivalent to 600 to 6,700 years of current level emissions from large stationary sources in the United States.[3]

Overview of Geologic Storage Potential in the United States (Source: U.S. Department of Energy, NATCARB)

Potential sequestration sites must undergo appropriate site characterization to ensure that the site can safely and securely store CO_2. After being transported to the sequestration site, the compressed CO_2 is injected deep underground into solid, but porous rock, such as sandstone, shale, dolomite, basalt, or deep coal seams. Suitable formations for CO_2 sequestration are located under one or more layers of cap rock, which trap the CO_2 and prevent upward migration. These sites are then rigorously monitored to ensure that the CO_2 remains permanently underground. The safety and security of CO_2 geologic sequestration is a priority for EPA.



For more information, visit the National Carbon Sequestration Database and Geographic Information System (NATCARB), a geographic information system (GIS)-based tool developed to provide an overview of CCS projects and storage potential.

Carbon Capture and Sequestration

Arguably the safest of the proposed geoengineering schemes, i.e., the one that is least invasive with respect to the Earth system, is *carbon capture and sequestration* (CCS). The main idea in this case is to prevent the carbon released during fossil fuel burning from ever getting into the atmosphere. In principle, this would allow for energy generation from fossil fuels with near zero carbon emissions. CCS is only economical when it can be applied to large point sources. In the context of energy generation, this applies almost exclusively to coal-fired power plants. CCS can also be used, however, to capture and sequester carbon emissions resulting from industrial processes, such as steel and cement manufacturing, petroleum refining, and paper mills.

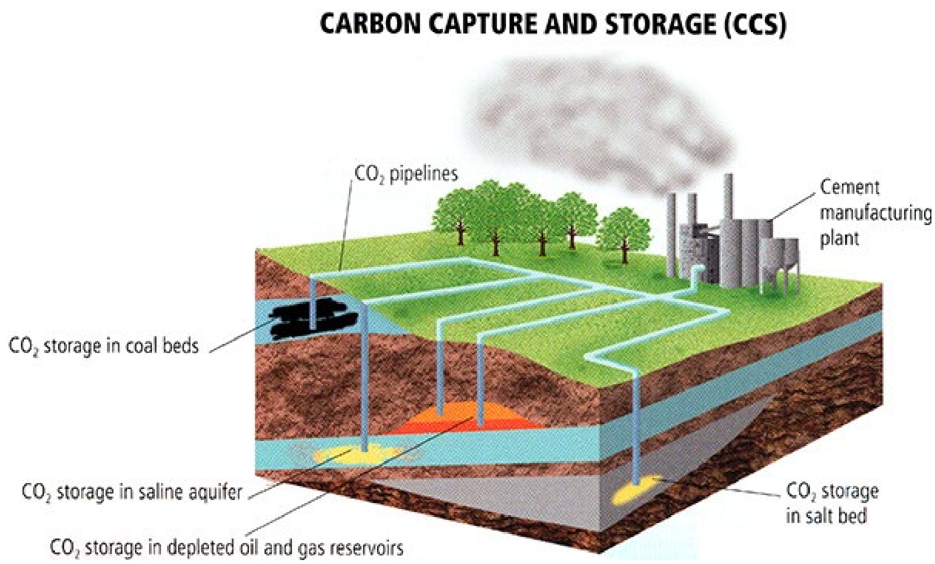


Figure 11.2: Carbon Capture and Sequestration.
Credit: Mann & Kump, *Dire Predictions: Understanding Climate Change, 2nd Edition © 2015 Pearson Education, Inc.*

While CCS has been implemented in various forms, the first full scale "proof of concept" for CCS in the context of coal-fired power generation was known as *FutureGen*, and was implemented in Illinois. Once operating, FutureGen would allow for the collection of data regarding efficiency, residual emissions, etc., and form a basis for evaluating performance that would be vital if and when CCS were to be deployed commercially at a larger scale in the future. The project was funded by an alliance of the Department of Energy and coal producers, users, and distributors.

Figure 11.3: Meredosia Power Plant in Illinois.
Credit: Dept. of Energy [1]

CO_2 released during electricity generation from coal burning is scrubbed from the emissions and captured, compressed and liquefied, and then pumped deep into the Earth (several km beneath the surface) where it is reacted with porous igneous rocks to form limestone. This approach mimics the geological processes that bury CO_2 on geological timescales, and provides a potential means for long-term geological sequestration of CO_2.

CO_2 is captured through a process known as *oxy-combustion*. This process burns coal in a pure mixture of O_2 and CO_2 (by first removing N_2 from the air), which results in relatively pure mixture of CO_2 after combustion, from which any residual pollutants (e.g., sulfate, nitrate, etc.) can be removed. The relatively pure remaining CO_2 is then compressed and liquefied, and the liquid CO_2 can readily be transported deep below for storage. FutureGen scientists estimate that they can annually bury roughly 1.3 million tons of CO_2 (i.e., 0.0013 Gigatons carbon per year), equivalent to roughly 90% of the carbon emitted by the plant's coal burning.

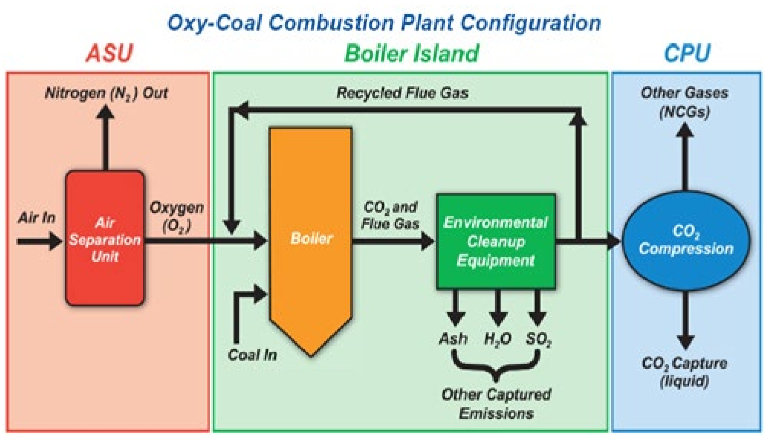


Figure 11.4: Processes used in carbon capture and compression.
Credit: The Babcock and Wilcox Company, FutureGen Alliance (used with permission).

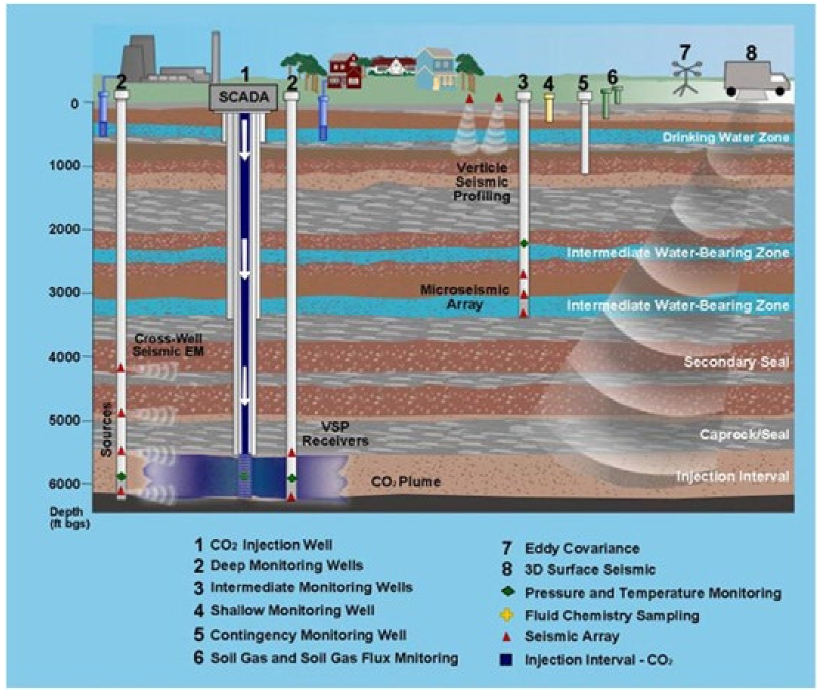
Why was FutureGen considered a good choice for testing the efficacy of this CCS? The geology of the Mount Simon site in Illinois is well suited for CCS, but it is also reasonably representative of geological formations found in many other regions of the world, so that whatever is learned from FutureGen could, in principle, be applied to many other potential CCS sites around the U.S. and the world.

Geological formations that contain salt water, like Mount Simon, are ideal because of their porosity. Moreover, there is impermeable caprock to seal in CO_2. The formation is deep, placing it well below the depth of aquifers that are tapped for fresh water supply.

More than anything else, FutureGen was proposed as an experiment. The FutureGen operation would have evaluated potential storage sites before deciding precisely where the liquefied CO_2 would have been injected for long-term storage, based on both theoretical modeling and data collection to evaluate detailed geological information about potential storage sites. The effectiveness of the injection system would be evaluated, and there would be continual monitoring of the burial process to ensure that CO_2 is indeed being sequestered and remains sequestered. Whatever is learned could, in principle, be applied to any full-scale future deployment of CCS in the U.S. and abroad.

Unfortunately, due to difficulties of committing public funds and acquiring public funds, the FutureGen project, reconstituted as the FutureGen 2.0 project, was finally suspended in February 2015 (read the article here [2]). The Kemper County pre-combustion CCS plant in Mississippi came in $4 billion over budget and finally switched to natural gas combustion without any CCS [3]. However, other CCS projects have started or should begin in the near future, such as the large post-combustion coal-based Petra Nova [4] project in Texas, and the sequestration of CO_2 [5] from ethanol production into the Mount Simon formation. Other CCS projects are working with non-coal based power plants, like the CarbFix program in Iceland [6].

Figure 11.5: Schematic Indicating how FutureGen CCS Would Be Monitored.
Credit: FutureGen Alliance, (used with permission)



CCS might sound like a fool-proof plan for mitigating greenhouse emissions, but many of the assumptions made above may be over-optimistic. Even if the 90% rate of sequestration were correct, that would mean that 10% of the CO_2 would still escape to the atmosphere, i.e., even in the best of scenarios, CCS-equipped coal-fired power plants would continue to emit CO_2 into the atmosphere, just less of it. Moreover, in the event of unforeseen events, such as earthquakes, or other seismic activity, or alterations in groundwater flow, the efficacy of CCS in any particular location could be compromised. That would mean that the great initial investment made to establish the CCS site would be wasted, and the economic viability of CCS vs. other schemes to lower the carbon intensity of energy production might be undermined.

Despite all of the talk these days about "clean coal technology," such technology — in the sense that "clean" is taken to mean energy that is free or nearly free of polluting greenhouse gases — does not yet exist and remains hypothetical. Until data from experimental sites such as FutureGen have been collected and studied for some years, it will be unclear how much CO_2 is actually being sequestered, and it would literally take decades until the efficacy of true long-term carbon burial could be established. Yet, we have seen that even a decade or so of additional business-as-usual greenhouse gas emissions could commit us to substantial and potentially detrimental future climate change. So CCS, despite the promise that it shows, may not be the "magic bullet" we are looking for.

Links
[1] http://www.fossil.energy.gov/programs/powersystems/futuregen/ [2] http://spectrum.ieee.org/energywise/green-tech/clean-coal/carbon-capture-is-not-dead-but-will-it-blossom [3] https://www.nrdc.org/experts/george-peridas/kemper-county-igcc-death-knell-carbon-capture-not [4] https://www.eia.gov/todayinenergy/detail.php?id=33552 [5] https://news.illinois.edu/view/6367/198417 [6] https://eos.org/articles/basalts-turn-carbon-into-stone-for-permanent-storage