RCSP Water Working Group

RCSP Water Working Group Annual Meeting

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Energy & Environmental Research Center (EERC)

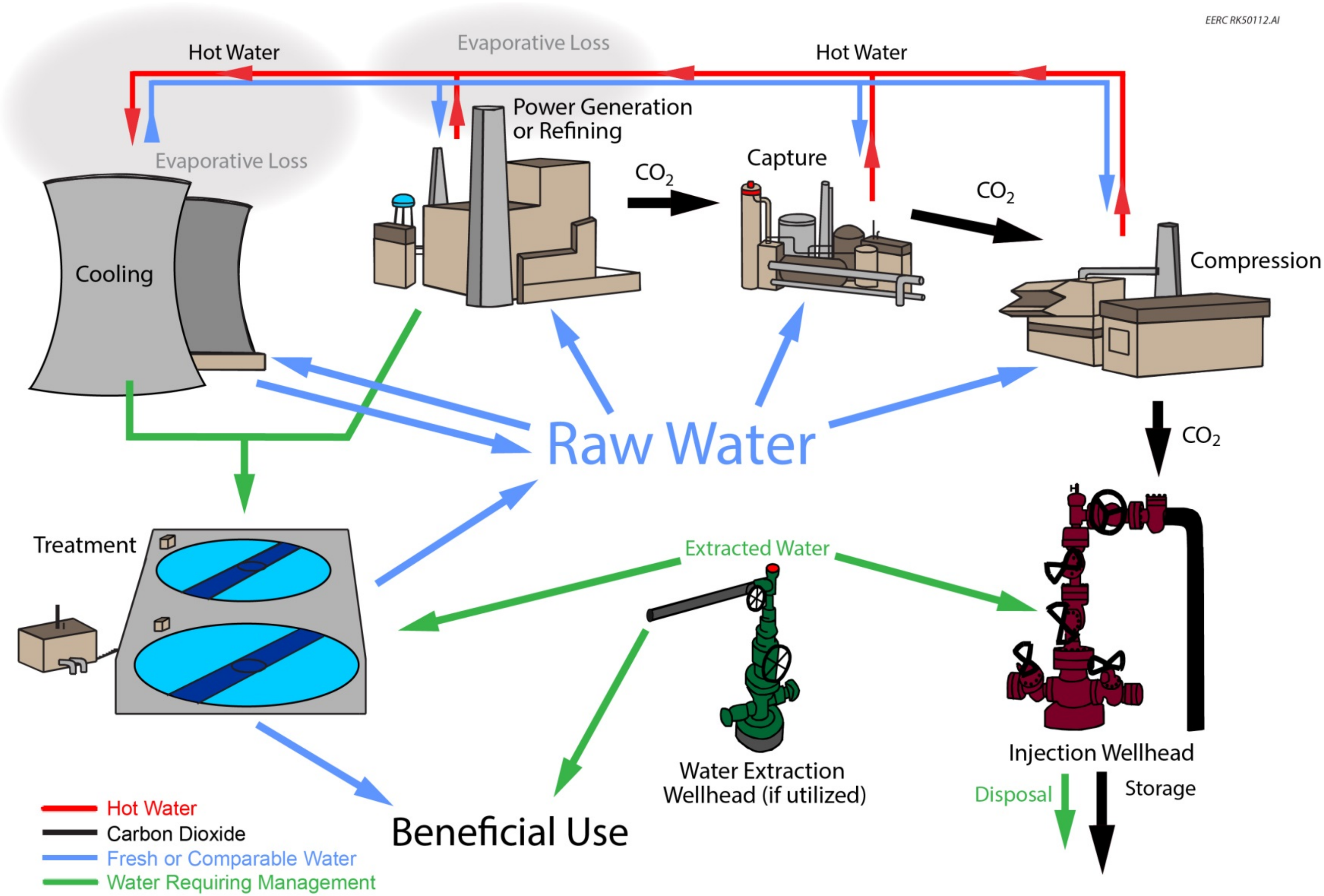
Putting Research into Practice

RCSP Water Working Group

Regional Carbon Sequestration Partnerships

- Water Working Group (WWG):
  - Composed of experts from government, academia, and industry who are members of the U.S. Department of Energy (DOE) National Energy Technology Laboratory (NETL) RCSP Program.
- Mission statement:
  - Address stakeholder concerns regarding emerging carbon capture and storage (CCS) technology and potential interactions with local and regional water resources.

The Water and CCS Nexus



Water and Capture

Capture

Compression

Transportation

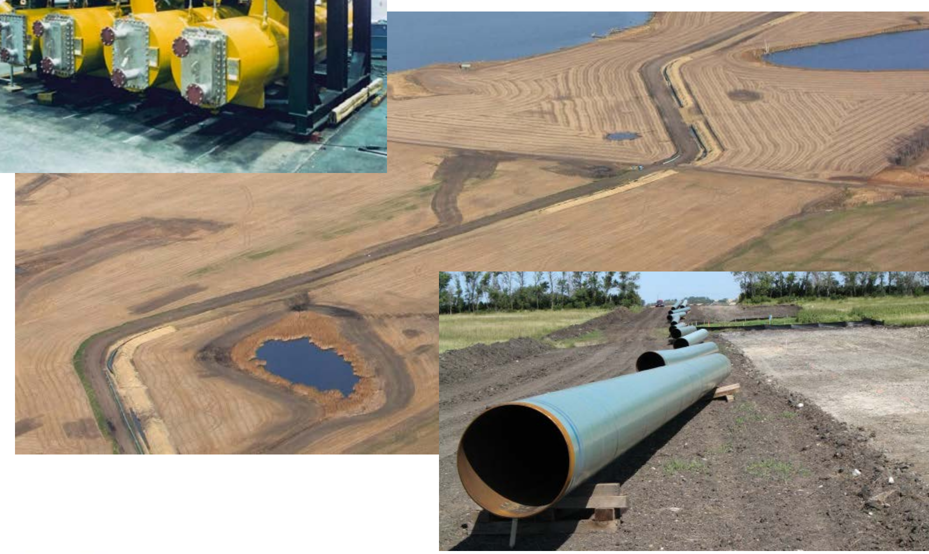
- Additional resources
  - Water: cooling, process water
  - Power
    - Replace power diverted to capture and compression

Water and Carbon Capture, Compression, and Transportation

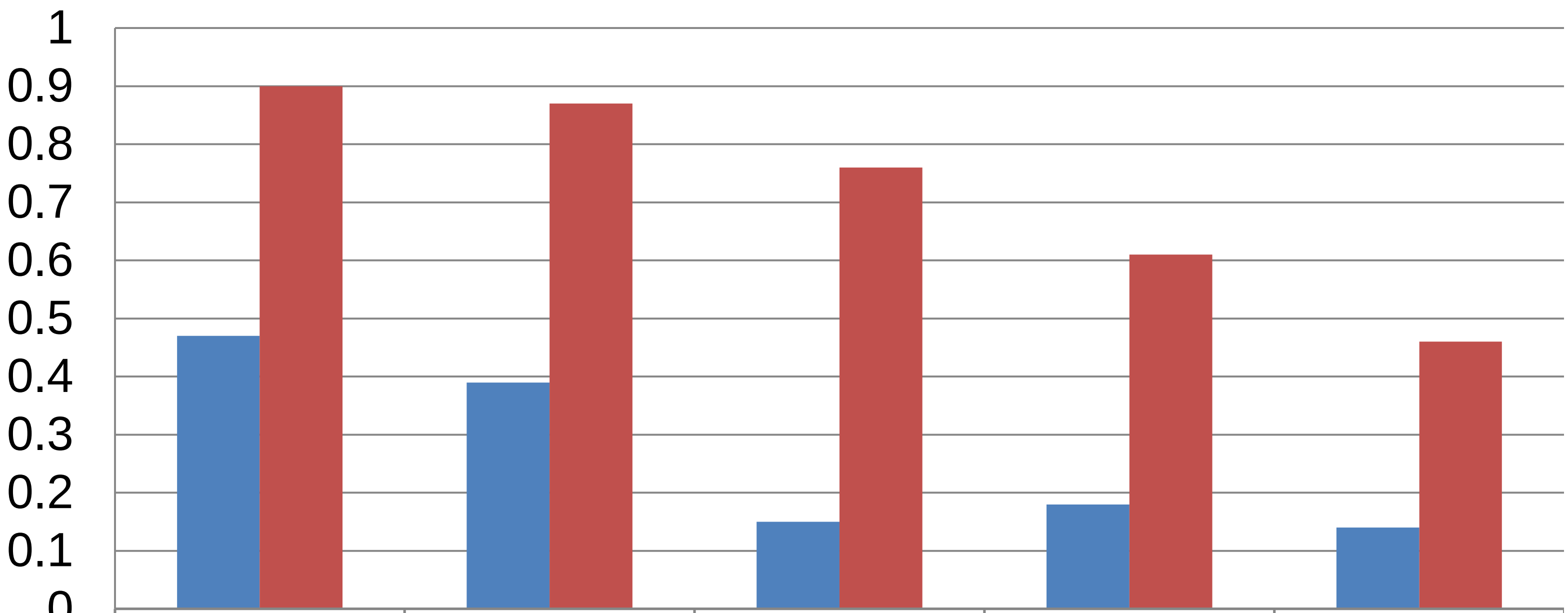
- Chemical or physical absorption
  - 15%–30% water increase
    - ♦ Additional cooling
    - ♦ Solvent/sorbent regeneration
    - ♦ Process-specific subprocesses

- Compressors represent a considerable additional energy load to a facility (generally 8%–10%) as well as a smaller water-related cooling load.

- Transportation costs are primarily related to pipeline construction.



Water and Carbon Capture



	Subcritical pc	Supercritical pc	NGCC	IGCC - dry feed	IGCC - slurry feed
gal/kWh	0.47	0.39	0.15	0.18	0.14
Fraction of total	0.90	0.87	0.76	0.61	0.46

Source: Gerdes, K., and Nichols, C., 2009, Water requirements for existing and emerging thermoelectric plant technologies: DOE/NETL Report 402/080108; U.S. Department of Energy National Energy Technology Laboratory: Morgantown, West Virginia.

Optimizing Carbon Capture Water Use

- Efficient process design
  - Update existing facilities
  - New technologies (e.g., compression)

- Alternative cooling technologies

- Alternative (degraded) water sources

Water and Carbon Storage

Injection

Extraction?

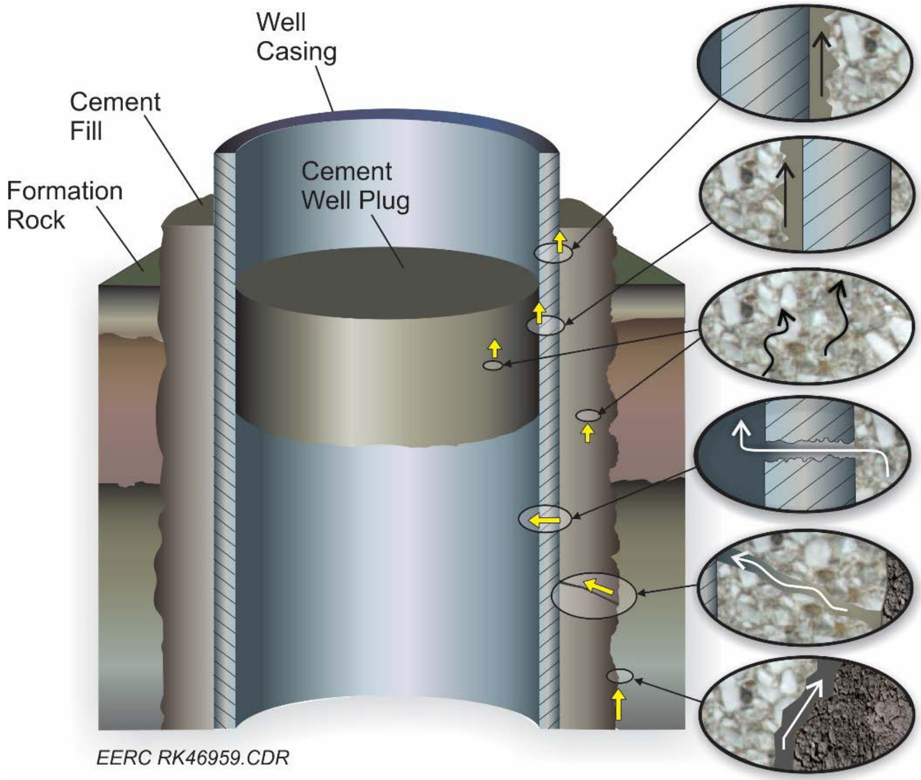
Treatment

- Storage formations almost certainly contain water.
  - Not suitable for drinking water (total dissolved solids [TDS] >10,000 ppm)
  - Potential for additional water resource (produced water associated with carbon storage)

Water and Carbon Storage

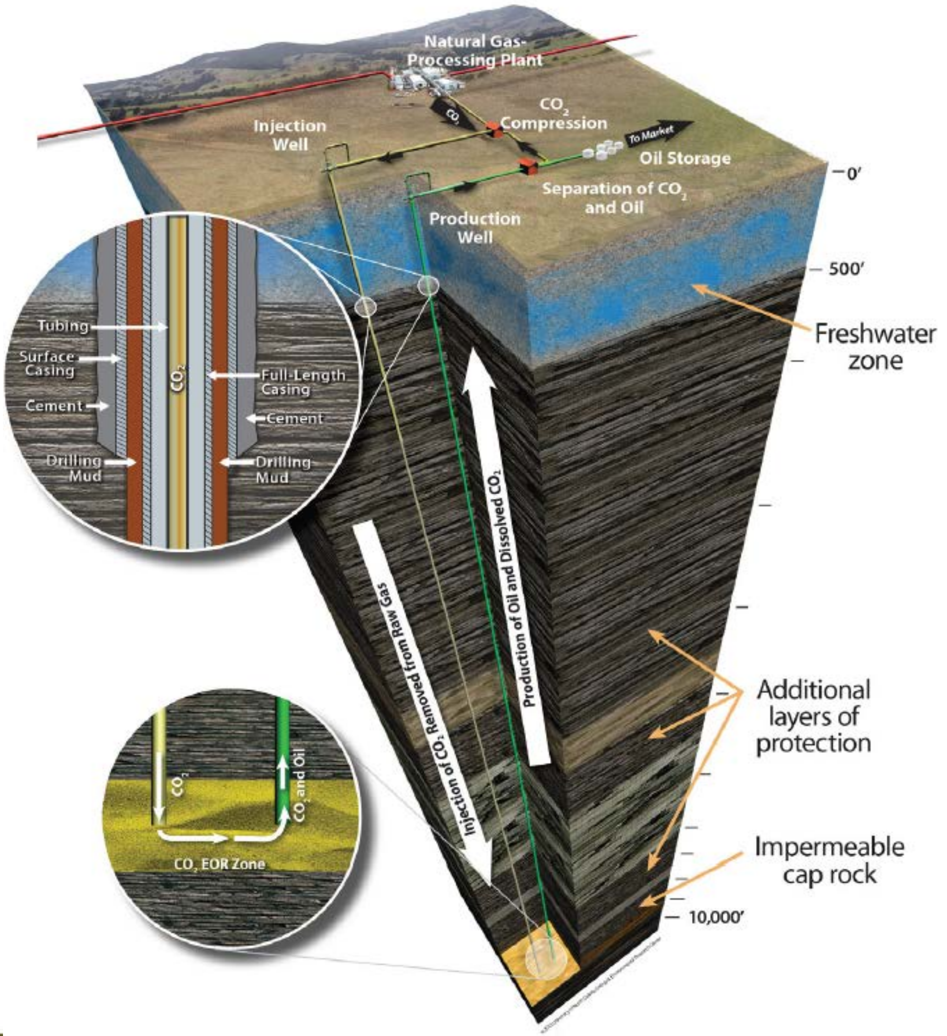
- Water resources:
  - Protect drinking water sources.
  - Minimize brine mobilization.

- Proper site characterization and selection along with monitoring, verification, and accounting (MVA) and appropriate regulatory compliance will ensure these goals are met.



Water and Carbon Storage

- Storage targets and water:
  - Oil/gas reservoirs, coal seams, saline aquifers
- Each represents unique storage environments.
- Water may be extracted from storage activities in order to:
  - Enhance recovery.
  - Increase storage volume.
  - Increase plume management control.



The Plains CO_2 Reduction Partnership PCOR Partnership | SECARB Southeast Regional Carbon Sequestration Partnership | West Coast Regional Carbon Sequestration Partnership westcarb.org | MRCSP Midwest Regional Carbon Sequestration Partnership | MGSC Midwest Geological Sequestration Consortium | SWP Southwest Partnership CO_2 Sequestration | Big Sky Carbon Sequestration Partnership | NETL

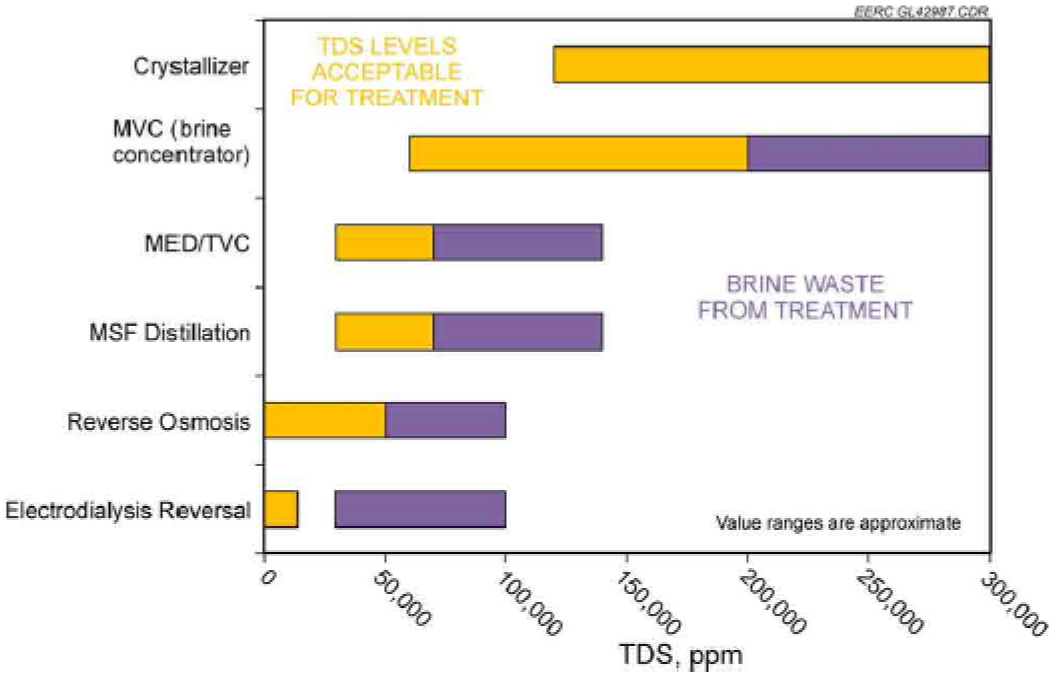
Extracted Water

- Typically, water extraction is expected to be avoided.

- If extracted, management strategies include:
  - Reinjection.
  - Minimal treatment for beneficial use.
  - Substantial treatment for beneficial use.

Options for Extracted-Water Management

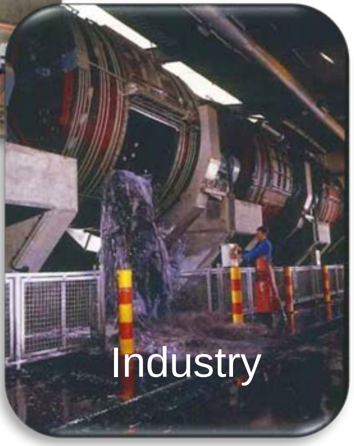
- Water quality potential for extracted water:
  – TDS range = low to very high.
- Water quality needed for beneficial use:
  – Most uses require lower TDS concentrations.
- Water treatment processes:
  – Desalination methods would be used to match extracted-water quality to water quality needs.



Extracted-Water Treatment Technologies

- Managing salinity
  - Reverse osmosis
  - Forward osmosis
  - Membrane filtration
    - ♦ Micro-, ultra-, and nanofiltration
  - Electrodialysis and electrodialysis reversal
  - Thermal treatment
    - ♦ Crystallizer, mechanical vapor compression/recompression, multieffect distillation, industrial evaporation, solar evaporation, and freeze–thaw/evaporation
  - Ion exchange and other deionization (e.g., Higgins Loop™)

CCS Produced Water – Beneficial Use Potential



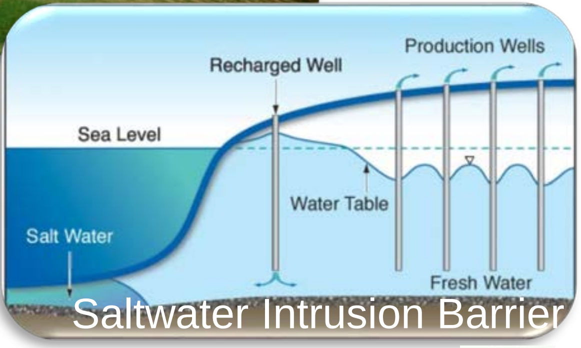
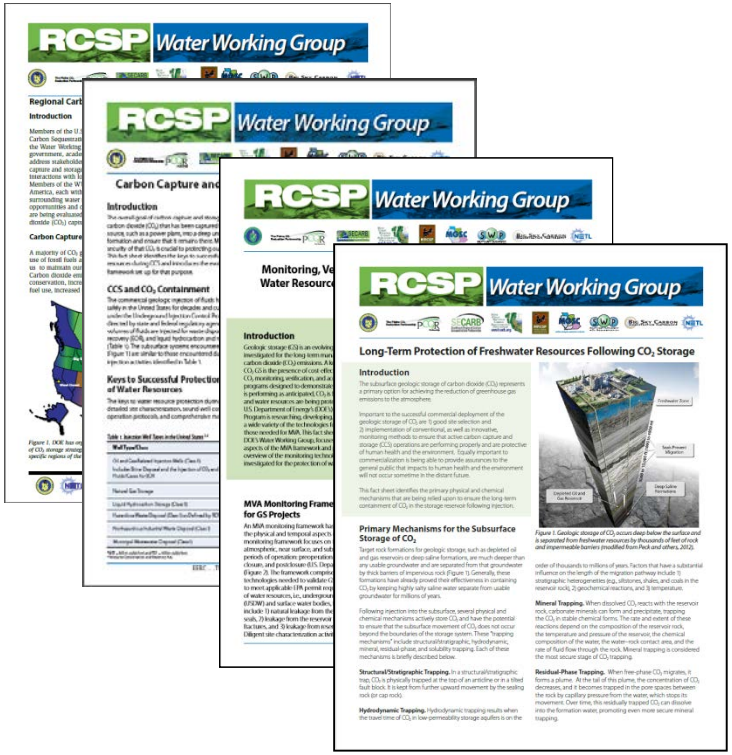


Diagram courtesy of Solinst

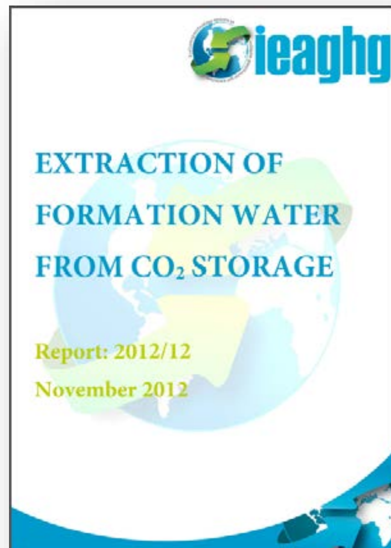
MVA

- **Imperative to any CCS operation.**
- **Establish baseline conditions for naturally occurring CO_2 levels present in surface water and shallow groundwater aquifers in the vicinity of the carbon storage formation.**
- **Provide a source of data to show that surface environments remain unaffected by fluid or gas migration and to identify the source and quantify of the impact of an out-of-zone migration event should it occur.**

Additional Information



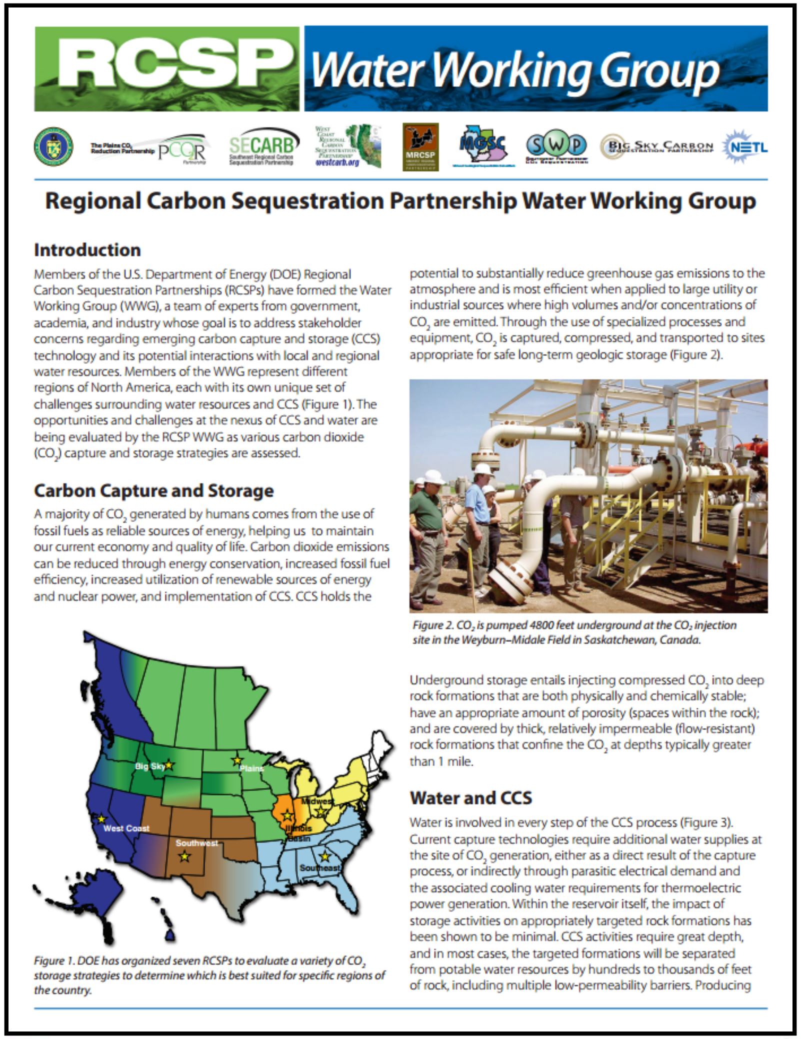
Fact Sheets



Reports

Presentations

Regional Carbon Sequestration Partnership Water Working Group



RCSP Water Working Group

Regional Carbon Sequestration Partnership Water Working Group

Introduction

Members of the U.S. Department of Energy (DOE) Regional Carbon Sequestration Partnerships (RCSPs) have formed the Water Working Group (WWG), a team of experts from government, academia, and industry whose goal is to address stakeholder concerns regarding emerging carbon capture and storage (CCS) technology and its potential interactions with local and regional water resources. Members of the WWG represent different regions of North America, each with its own unique set of challenges surrounding water resources and CCS (Figure 1). The opportunities and challenges at the nexus of CCS and water are being evaluated by the RCSP WWG as various carbon dioxide (CO_2) capture and storage strategies are assessed.

Carbon Capture and Storage

A majority of CO_2 generated by humans comes from the use of fossil fuels as reliable sources of energy, helping us to maintain our current economy and quality of life. Carbon dioxide emissions can be reduced through energy conservation, increased fossil fuel efficiency, increased utilization of renewable sources of energy and nuclear power, and implementation of CCS. CCS holds the potential to substantially reduce greenhouse gas emissions to the atmosphere and is most efficient when applied to large utility or industrial sources where high volumes and/or concentrations of CO_2 are emitted. Through the use of specialized processes and equipment, CO_2 is captured, compressed, and transported to sites appropriate for safe long-term geologic storage (Figure 2).

Figure 1. DOE has organized seven RCSPs to evaluate a variety of CO_2 storage strategies to determine which is best suited for specific regions of the country.

Figure 2. CO_2 is pumped 4800 feet underground at the CO_2 injection site in the Weyburn–Midale Field in Saskatchewan, Canada.

Underground storage entails injecting compressed CO_2 into deep rock formations that are both physically and chemically stable; have an appropriate amount of porosity (spaces within the rock); and are covered by thick, relatively impermeable (flow-resistant) rock formations that confine the CO_2 at depths typically greater than 1 mile.

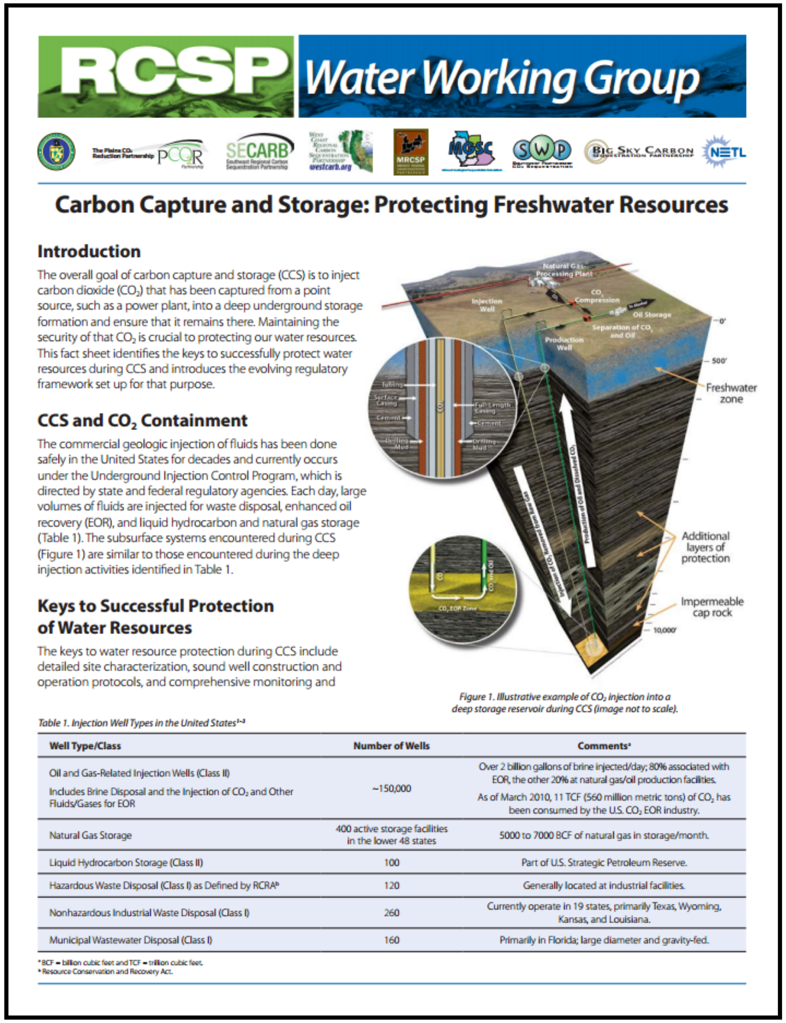
Water and CCS

Water is involved in every step of the CCS process (Figure 3). Current capture technologies require additional water supplies at the site of CO_2 generation, either as a direct result of the capture process, or indirectly through parasitic electrical demand and the associated cooling water requirements for thermoelectric power generation. Within the reservoir itself, the impact of storage activities on appropriately targeted rock formations has been shown to be minimal. CCS activities require great depth, and in most cases, the targeted formations will be separated from potable water resources by hundreds to thousands of feet of rock, including multiple low-permeability barriers. Producing

- Who is the WWG?
- What is the water and CCS nexus?
- What are the opportunities and challenges associated with water and CCS?

Carbon Capture and Storage: Protecting Freshwater Resources

- How is freshwater protected?
- What steps need to be taken?
- What are the existing regulations?
- What steps are needed for commercial deployment?


RCSP Water Working Group

Carbon Capture and Storage: Protecting Freshwater Resources

Introduction

The overall goal of carbon capture and storage (CCS) is to inject carbon dioxide (CO_2) that has been captured from a point source, such as a power plant, into a deep underground storage formation and ensure that it remains there. Maintaining the security of that CO_2 is crucial to protecting our water resources. This fact sheet identifies the keys to successfully protect water resources during CCS and introduces the evolving regulatory framework set up for that purpose.

CCS and CO_2 Containment

The commercial geologic injection of fluids has been done safely in the United States for decades and currently occurs under the Underground Injection Control Program, which is directed by state and federal regulatory agencies. Each day, large volumes of fluids are injected for waste disposal, enhanced oil recovery (EOR), and liquid hydrocarbon and natural gas storage (Table 1). The subsurface systems encountered during CCS (Figure 1) are similar to those encountered during the deep injection activities identified in Table 1.

Keys to Successful Protection of Water Resources

The keys to water resource protection during CCS include detailed site characterization, sound well construction and operation protocols, and comprehensive monitoring and

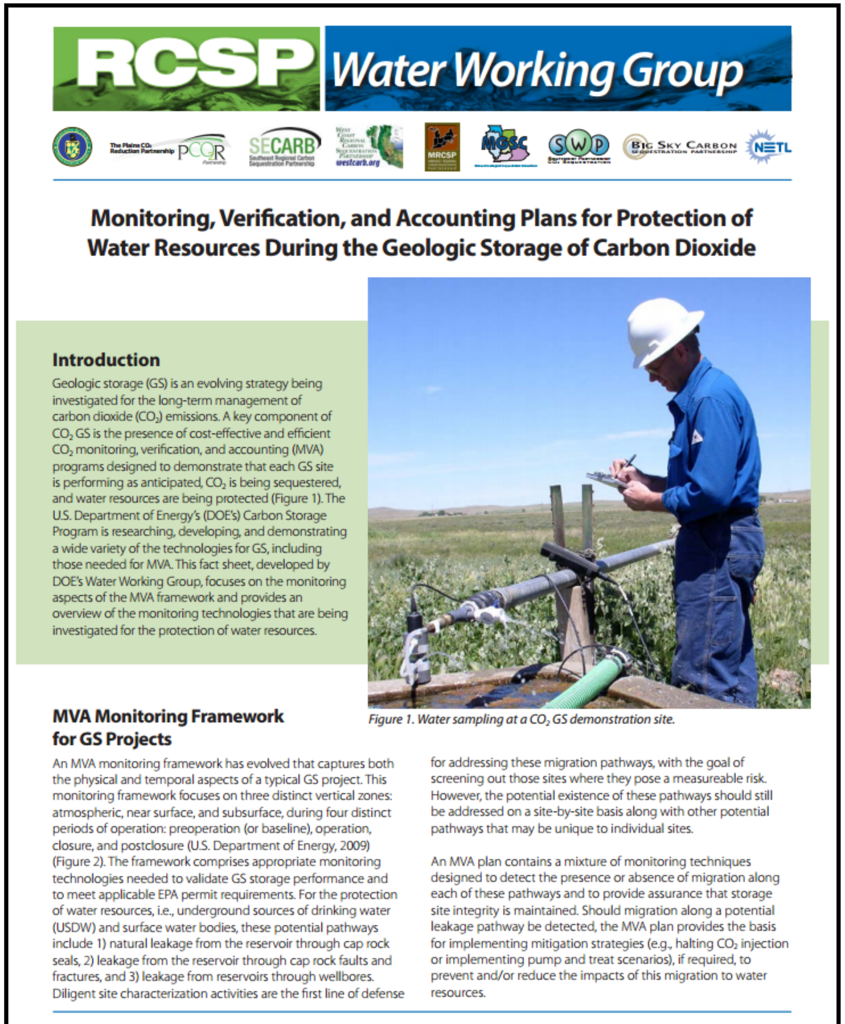
Figure 1. Illustrative example of CO_2 injection into a deep storage reservoir during CCS (image not to scale).

Table 1. Injection Well Types in the United States[1–3]

Well Type/Class	Number of Wells	Comments[a]
Oil and Gas-Related Injection Wells (Class II) Includes Brine Disposal and the Injection of CO_2 and Other Fluids/Gases for EOR	~150,000	Over 2 billion gallons of brine injected/day; 80% associated with EOR, the other 20% at natural gas/oil production facilities. As of March 2010, 11 TCF (560 million metric tons) of CO_2 has been consumed by the U.S. CO_2 EOR industry.
Natural Gas Storage	400 active storage facilities in the lower 48 states	5000 to 7000 BCF of natural gas in storage/month.
Liquid Hydrocarbon Storage (Class II)	100	Part of U.S. Strategic Petroleum Reserve.
Hazardous Waste Disposal (Class I) as Defined by RCRA[b]	120	Generally located at industrial facilities.
Nonhazardous Industrial Waste Disposal (Class I)	260	Currently operate in 19 states, primarily Texas, Wyoming, Kansas, and Louisiana.
Municipal Wastewater Disposal (Class I)	160	Primarily in Florida; large diameter and gravity-fed.

[a] BCF = billion cubic feet and TCF = trillion cubic feet.
[b] Resource Conservation and Recovery Act.

Monitoring, Verification, and Accounting Plans for Protection of Water Resources During the Geologic Storage of Carbon Dioxide



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Monitoring, Verification, and Accounting Plans for Protection of Water Resources During the Geologic Storage of Carbon Dioxide

Introduction

Geologic storage (GS) is an evolving strategy being investigated for the long-term management of carbon dioxide (CO_2) emissions. A key component of CO_2 GS is the presence of cost-effective and efficient CO_2 monitoring, verification, and accounting (MVA) programs designed to demonstrate that each GS site is performing as anticipated, CO_2 is being sequestered, and water resources are being protected (Figure 1). The U.S. Department of Energy's (DOE's) Carbon Storage Program is researching, developing, and demonstrating a wide variety of the technologies for GS, including those needed for MVA. This fact sheet, developed by DOE's Water Working Group, focuses on the monitoring aspects of the MVA framework and provides an overview of the monitoring technologies that are being investigated for the protection of water resources.

Figure 1. Water sampling at a CO_2 GS demonstration site.

MVA Monitoring Framework for GS Projects

An MVA monitoring framework has evolved that captures both the physical and temporal aspects of a typical GS project. This monitoring framework focuses on three distinct vertical zones: atmospheric, near surface, and subsurface, during four distinct periods of operation: preoperation (or baseline), operation, closure, and postclosure (U.S. Department of Energy, 2009) (Figure 2). The framework comprises appropriate monitoring technologies needed to validate GS storage performance and to meet applicable EPA permit requirements. For the protection of water resources, i.e., underground sources of drinking water (USDW) and surface water bodies, these potential pathways include 1) natural leakage from the reservoir through cap rock seals, 2) leakage from the reservoir through cap rock faults and fractures, and 3) leakage from reservoirs through wellbores. Diligent site characterization activities are the first line of defense for addressing these migration pathways, with the goal of screening out those sites where they pose a measureable risk. However, the potential existence of these pathways should still be addressed on a site-by-site basis along with other potential pathways that may be unique to individual sites.

An MVA plan contains a mixture of monitoring techniques designed to detect the presence or absence of migration along each of these pathways and to provide assurance that storage site integrity is maintained. Should migration along a potential leakage pathway be detected, the MVA plan provides the basis for implementing mitigation strategies (e.g., halting CO_2 injection or implementing pump and treat scenarios), if required, to prevent and/or reduce the impacts of this migration to water resources.

- How does MVA protect water resources?
- What technologies are available?
- How is MVA carried out at large-scale projects?
- What is required for successful deployment?

Long-Term Protecion of Freshwater Resources Following CO_2 Storage

- How is long-term storage achieved? How do we know freshwater resources are protected in the long-term?
- What are the dominant CO_2 storage mechanisms?
- How is long-term storage demonstrated by RCSP programs?

RCSP Water Working Group

Long-Term Protection of Freshwater Resources Following CO_2 Storage

Introduction

The subsurface geologic storage of carbon dioxide (CO_2) represents a primary option for achieving the reduction of greenhouse gas emissions to the atmosphere.

Important to the successful commercial deployment of the geologic storage of CO_2 are 1) good site selection and 2) implementation of conventional, as well as innovative, monitoring methods to ensure that active carbon capture and storage (CCS) operations are performing properly and are protective of human health and the environment. Equally important to commercialization is being able to provide assurances to the general public that impacts to human health and the environment will not occur sometime in the distant future.

This fact sheet identifies the primary physical and chemical mechanisms that are being relied upon to ensure the long-term containment of CO_2 in the storage reservoir following injection.

Figure 1. Geologic storage of CO_2 occurs deep below the surface and is separated from freshwater resources by thousands of feet of rock and impermeable barriers (modified from Peck and others, 2012).

Primary Mechanisms for the Subsurface Storage of CO_2

Target rock formations for geologic storage, such as depleted oil and gas reservoirs or deep saline formations, are much deeper than any usable groundwater and are separated from that groundwater by thick barriers of impervious rock (Figure 1). Generally, these formations have already proved their effectiveness in containing CO_2 by keeping highly salty saline water separate from usable groundwater for millions of years.

Following injection into the subsurface, several physical and chemical mechanisms actively store CO_2 and have the potential to ensure that the subsurface movement of CO_2 does not occur beyond the boundaries of the storage system. These "trapping mechanisms" include structural/stratigraphic, hydrodynamic, mineral, residual-phase, and solubility trapping. Each of these mechanisms is briefly described below.

Structural/Stratigraphic Trapping. In a structural/stratigraphic trap, CO_2 is physically trapped at the top of an anticline or in a tilted fault block. It is kept from further upward movement by the sealing rock (or cap rock).

Hydrodynamic Trapping. Hydrodynamic trapping results when the travel time of CO_2 in low-permeability storage aquifers is on the order of thousands to millions of years. Factors that have a substantial influence on the length of the migration pathway include 1) stratigraphic heterogeneities (e.g., siltstones, shales, and coals in the reservoir rock), 2) geochemical reactions, and 3) temperature.

Mineral Trapping. When dissolved CO_2 reacts with the reservoir rock, carbonate minerals can form and precipitate, trapping the CO_2 in stable chemical forms. The rate and extent of these reactions depend on the composition of the reservoir rock, the temperature and pressure of the reservoir, the chemical composition of the water, the water–rock contact area, and the rate of fluid flow through the rock. Mineral trapping is considered the most secure stage of CO_2 trapping.

Residual-Phase Trapping. When free-phase CO_2 migrates, it forms a plume. At the tail of this plume, the concentration of CO_2 decreases, and it becomes trapped in the pore spaces between the rock by capillary pressure from the water, which stops its movement. Over time, this residually trapped CO_2 can dissolve into the formation water, promoting even more secure mineral trapping.

WWG Web Site

www.netl.doe.gov/research/coal/carbon-storage/wwg

Future Activity

- The WWG is focused on developing a final capstone document summarizing the “state of the science” at the nexus of water and CCS. Expected to be completed fall 2016.

- Developing a Special Issue of the *International Journal of Greenhouse Gas Control* centered on these issues, with participation from authors beyond the WWG. Expected to be published spring 2016.

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