Petroleum Traps as CO_2 Sequestration Sites: Assessing the Number and Size for Long-term CO_2 Storage

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Basic ideas:

- Oil and gas accumulations and CO_2-rich gas fields demonstrate that subsurface structures can store fluids like CO_2 for thousands to millions of years.
- The integrity of natural traps provides confidence that CO_2 will remain sequestered for similar periods of time.

Goal:

- A first-order, national scale assessment of the potential volume of petroleum traps as sequestration sites over the lifetime of sequestration projects. In other words, how long can an individual project accumulate CO_2?

Approach:

- Compare the volume of CO_2 emitted by individual power plants with the number and size of known petroleum accumulations.

Rationale:

1. CO_2 is bouyant and behaves like petroleum at subsurface conditions
2. Trap volume can be defined
3. Traps are the best characterized features of saline formations
4. Geologic integrity: traps have seals
5. Well defined traps are critical for measurement, monitoring, and verification activities (MMV).
6. Assessments of "undiscovered" traps (additional sequestration capacity) can be based on existing petroleum resource assessment methods.
7. Enhanced oil recovery (EOR) and gas recovery is possible
8. Geographic distribution of largest sources and sinks will indicate the scale of the pipeline network required for sequestration.

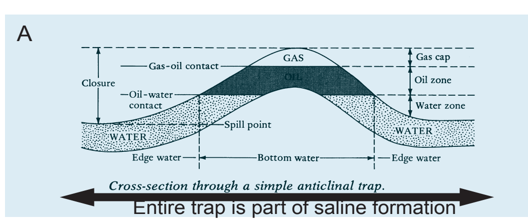
Sequestration assessment strategies based on petroleum traps

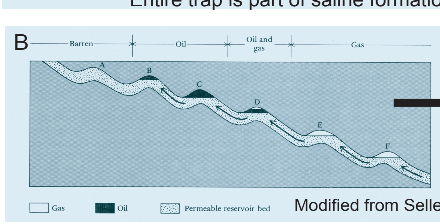
1. Cumulative production (Burruss, 1999, and Benson, 1999).
2. Number and size of traps based on known petroleum resources (this study).

Basic concepts of filling traps with with bouyant fluids (oil, gas, CO_2):

1. A trap is a three dimensional permeability barrier that can retain bouyant fluids. Not all traps are filled (Figure A modified from Selley, 1985).

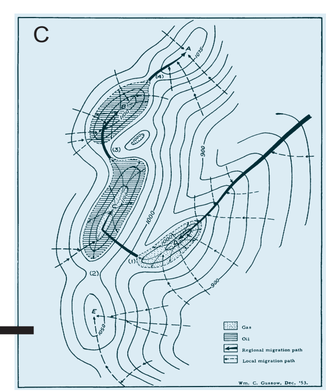
2. Fluids that are bouyant in saline formation water rise to fill traps to the spill point. Additional fluid rises and "spills" to the next higher trap, known as Gussow's Principle of differential entrapment (Gussow, 1954, illustrated in Figure B and C.) For detailed discussion see Schowalter (1979).





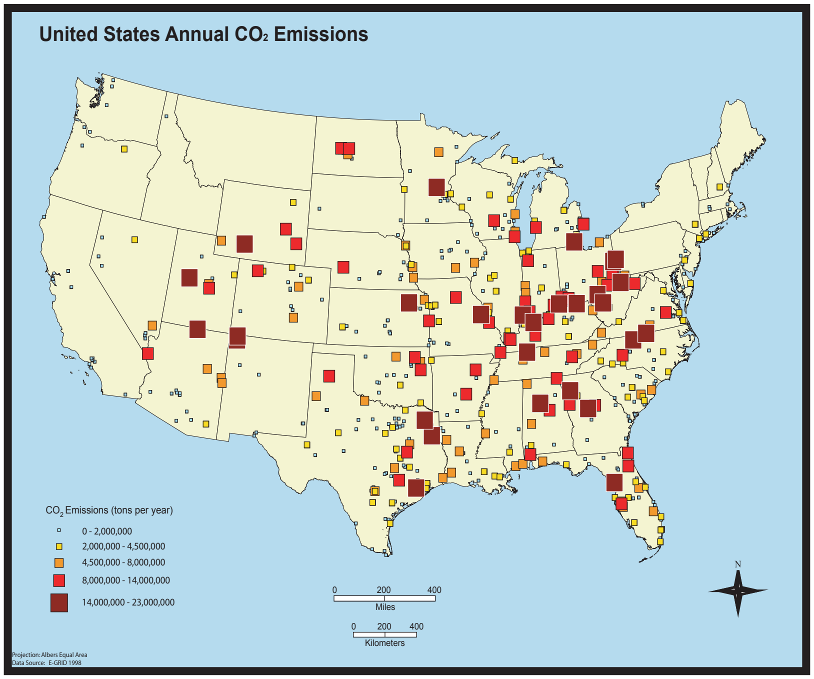
Modified from Selley, 1985

Hypothetical traps in sedimentary basins:
Cross-section
Plan view



Modified from Gussow, 1954

CO_2 sources, coal-fired power plants, >100MW



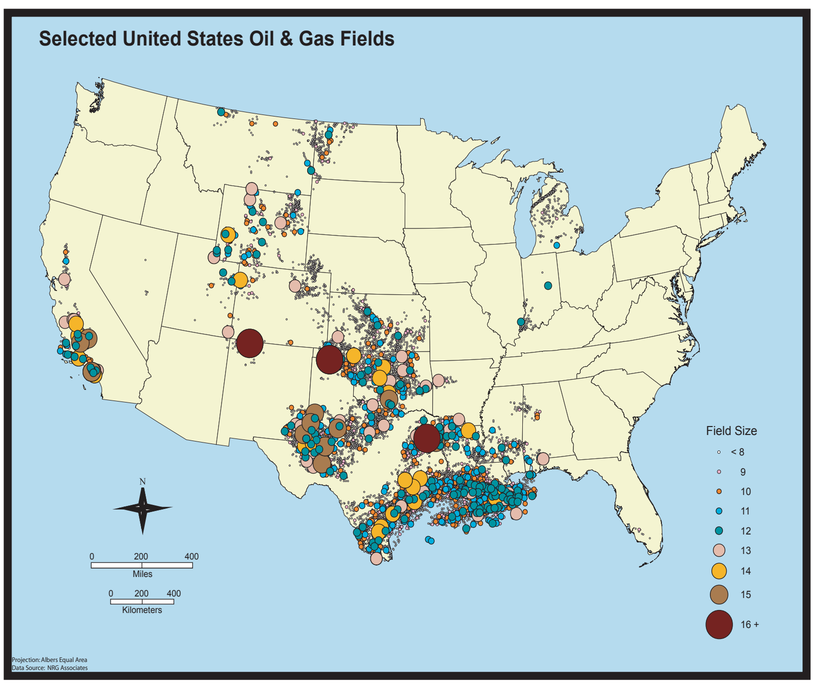
Conversion of power plant CO_2 emissions in short tons to barrels of oil equivalent (BOE):

Specific Sequestration Volume (SSV) calculated for a CO_2 density of 604 kg/m^3, equivalent to subsurface temperature and pressure of 60 ^{o}C and 150 bars (about 1.5 km depth, Brennan and Burruss, 2003).

SSV (BOE) = 9.447 b/ton

Note: CO_2 density used in this calculation is relatively low. At greater depths, the density will be up to 20% higher and sequestration volumes 20% lower.

Potential Sequestration in Petroleum Traps

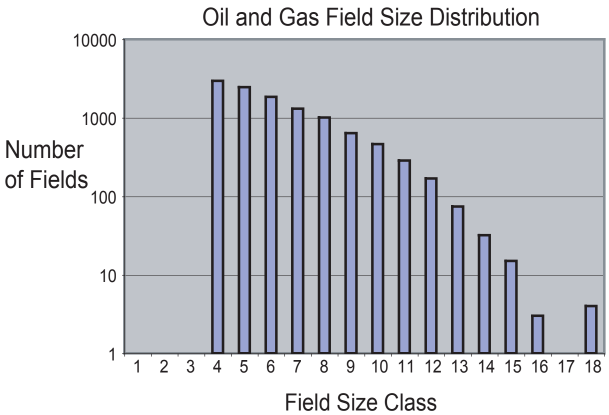


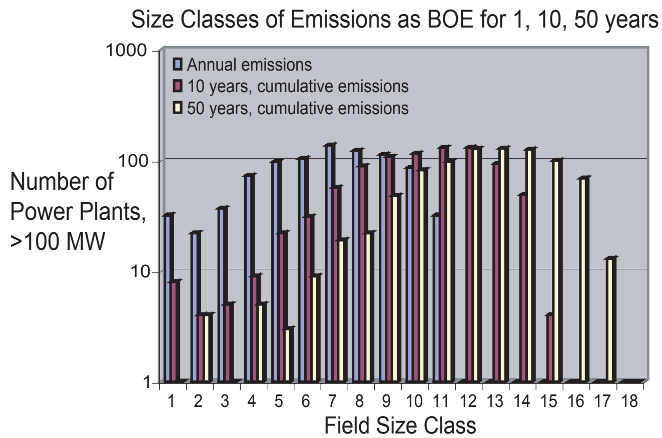
Petroleum field class size, units: 1,000,000 BOE

Size Class	Minimum - Maximum
1	0.00 - 0.25
2	0.25 - 0.50
3	0.50 - 1.00
4	1 - 2
5	2 - 4
6	4 - 8
7	8 - 16
8	16 - 32
9	32 - 64
10	64 - 128
11	128 - 256
12	256 - 512
13	512 - 1,024
14	1,024 - 2,048
15	2,048 - 4,096
16	4,096 - 8,192
17	8,192 - 16,834
18	16,834 - 32,768

Source: NRG Associates

Acknowledgements
We thank Kristin Dennen for assistance with data retrievals and displays from the NRG Associates database.





Discussion and Conclusions:

- Known oil and gas reservoirs in the United States have enough capacity to accumulate emissions from coal-fired power plants for at least several decades. The geological charactieristics of petroleum traps indicates that the CO_2 should be sequestered for thousands to millions of years. The volumes evaluated in this study are less than the maximum storage capacity of the trap.

- Current CO_2 emissions from coal-fired power plants are about 25 % of total U.S. emissions. If future power generation switches to H_2 production from coal or natural gas, the “demand” for geologic storage capacity for CO_2 will rise rapidly. This may require sequestration in areas of saline formations that are beyond the spillpoints of known trapping systems.

Issues for further work

1. The currently available national scale database of oil and gas fields from NRG Associates contains no data for the Appalachian basin and incomplete data for the Illinois basin. To expand coverage to a full national assessment will require incorporation of the results of the MID-CARB Project and statistics from the other eastern states with oil and gas production.

2. Using the volume of known reserves (cumulative production plus proved reserves) is a minimum estimate of trap volume. Proved reserves grow with time and additional volume within the trap is occupied by non-recoverable petroleum and residual saline formation water.

3. Many oil and gas reservoirs may be at pressures and temperatures that are not optimum for CO_2 EOR. Potential recovery of additional resources is still possible and criteria should be established to estimate recoveries from “non-optimum” EOR (see discussion in Shaw and Bachu, 2002).

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