Working Group Final Report

To do list for G&T Subcommittee:

- Seismicity – further work, consider including USGS seismicity map
- Review RCSP use of MVA technology for inclusion in Final Report
- Review risk assessment for further refinement
- Improve estimate of storage volume occupied for a given amount of CO\textsubscript{2} in the reservoir
  - Re-visit storage volume estimates in Preliminary Report

Other items to consider:

- Exporting captured CO\textsubscript{2} for EOR
- New UIC Class VI regulations
- Financial responsibility
- Long-term liability
Working Group Final Report

To do list for Working Group:

• Assess the economic and environmental feasibility of large, long-term carbon dioxide sequestration operations [§22-11A-6(h)(2)].
• Identify areas of research needed to better understand and quantify the processes of carbon dioxide sequestration [§22-11A-6(h)(9)].
• Outline the working group’s long-term strategy for the regulation of carbon dioxide sequestration in West Virginia [§22-11A-6(h)(10)].
- NETL released the 3rd edition of their sequestration atlas
- USGS is moving ahead with their assessment of storage potential
  - Their model is illustrated above

• For any given depth, storage efficiency is critical
  – Efficiency values used here from NETL’s Atlas 3rd edition, found at:

• Illustrates potential importance of efficiency – but what mechanisms, if any, can be used to improve efficiency?
  – Some research suggest production of formation waters can increase storage efficiency/control storage area
    • LLNL active reservoir management: https://str.llnl.gov/Dec10/pdfs/12_10.4.pdf
  – Some research suggest co-injection of formation waters can increase storage efficiency
#6 – Assess Feasibility of CO$_2$ Sequestration…

Stratigraphic Cross-Section

Rome Trough

Allegheny Structural Front
### West Virginia: CO₂ Storage Resource Potential


<table>
<thead>
<tr>
<th>Source</th>
<th>Low</th>
<th>High</th>
<th>Low</th>
<th>High</th>
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<tbody>
<tr>
<td>Sources</td>
<td>30</td>
<td>26</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Emissions</td>
<td>102.1</td>
<td>99</td>
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<tr>
<td>Oil &amp; Gas</td>
<td>1,353</td>
<td>1,353</td>
<td>1,830</td>
<td>1,830</td>
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<tr>
<td>Coal</td>
<td>177</td>
<td>177</td>
<td>320</td>
<td>500</td>
</tr>
<tr>
<td>Saline</td>
<td>3,343</td>
<td>13,463</td>
<td>4,480</td>
<td>17,930</td>
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<tr>
<td>TOTAL</td>
<td>4,873</td>
<td>14,994</td>
<td>6,630</td>
<td>20,260</td>
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<tr>
<td>Years Injection</td>
<td>47</td>
<td>146</td>
<td>66</td>
<td>204</td>
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</tbody>
</table>

All emission and storage values are in Million Metric Tons. Coal means unmineable coal.

- **Estimates of Storage Efficiency have changed**
  - Saline: from 1% - 4% in 2008 to 0.4% - 5.5% in 2010
  - Coal: from 28% - 40% in 2008 to 21% - 48% in 2010 for overall storage efficiency

- **Oil & Gas storage potential based on production estimates**
  - Assume 100% efficiency for pressure depleted reservoir volume
**West Virginia: Change in CO₂ Storage Resource Potential**

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<thead>
<tr>
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</thead>
<tbody>
<tr>
<td></td>
<td>Low</td>
<td>High</td>
</tr>
<tr>
<td>Change in Sources</td>
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<td>-13.3</td>
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<tr>
<td>Change in Emissions</td>
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<td>Oil &amp; Gas - % of Total</td>
<td>27.8</td>
<td>9.0</td>
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<tr>
<td>Coal - % of Total</td>
<td>3.6</td>
<td>1.2</td>
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<tr>
<td>Saline % of Total</td>
<td>68.6</td>
<td>89.8</td>
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<tr>
<td>% Change in TOTAL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>% Increase in Injection Years</td>
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</tbody>
</table>

- Slight increase in Coal storage potential along with slight decrease in Saline storage potential.
- Significant increase in overall storage potential.
- Significant increase in potential injection time span.
### Appalachian Basin:
**CO$_2$ Storage Resource Potential**

<table>
<thead>
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<tbody>
<tr>
<td></td>
<td>Low</td>
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<tr>
<td>Sources</td>
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<td>Emissions</td>
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<td>Oil &amp; Gas</td>
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<td>Coal</td>
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<tr>
<td>Saline</td>
<td>18,350</td>
<td>73,932</td>
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<td>TOTAL</td>
<td>26,879</td>
<td>82,462</td>
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<tr>
<td>Years Injection</td>
<td>55</td>
<td>170</td>
</tr>
</tbody>
</table>

- New York, Ohio, Pennsylvania and West Virginia have:
  - 14% of the sources
  - 15.3% of the emissions
  - 2.6% of the low estimated storage potential (0.6% of the high estimate)

New York, Ohio, Pennsylvania and West Virginia
All emission and storage values are in Million Metric Tons.
Coal means unmineable coal.

• Storage potential estimates are a resource value that have yet to be proven
There are other formations with oil & gas potential. A geologic column for West Virginia is also posted in the Preliminary Report.
Primarily in western part of the State

Potential distribution of CO₂ storage reservoirs. Saline reservoirs may be found outside the oil & gas field area illustrated here.
Storage Potential Impact on Costs

Porosity and Permeability

• Permeability
  – Controls injectivity and number of wells required to sequester a given amount of captured CO₂
  – Monitor wells required for each injection well
    • Above and within injection zone
  – Spare injection capacity to accommodate injection well maintenance

• Porosity
  – Storage capacity restricted by efficiency
  – Net height of injection zone (also impacts injectivity)
  – Reservoir architecture – distribution of porosity and permeability
  – All directly impact areal extent of CO₂ plume

• Production of formation fluids (waters)
  – Maintain injectivity, influence pressure
  – Potential to increase storage efficiency
  – Add costs: permits, operations, water treatment/disposal
Storage Potential Impact on Costs

$Q_w$ – Injection rate: permeability, number of injection wells.
$h$ – height of injection zone: reservoir architecture, porosity & efficiency, injectivity.

• Diagram illustrates density difference between formation waters and CO$_2$ on development of CO$_2$ plume.
• Preliminary research suggests co-injection of water and CO$_2$ may better utilize the full height of the reservoir

Diagram source – Sean McCoy, CMU
**CO₂ - EOR**

- A market mechanism for deployment of CCS technology
- Potential for CO₂-EOR to consume all of the CO₂ captured over the first two decades
  - Assuming all captured CO₂ is delivered to EOR projects
- ARI-NRDC study
- Potential to accelerate deployment:
  - Three years to characterize and build saline storage operations
    - Maybe longer: four years for saline gas storage development
    - An exploration component to developing saline storage – success factor
    - EPA assumes a 25% success rate in establishing saline storage reservoirs
  - 8 months to 18 months to begin CO₂ injection for EOR project
    - But several years to establish positive cash flow
- Possible option for West Virginia to export captured CO₂
  - Competition with other states
  - Look at Appalachian/Mid-West opportunities
CO$_2$ - EOR

- Permian Basin EOR fields in production decline due to tight supply of CO$_2$
- EOR production growing overall with expansions in Wyoming and Gulf Coast
- EOR projects sensitive to cost of CO$_2$
- CO$_2$ single largest expense over life of EOR project
- Cost of CO$_2$ sensitive to cost of capture and transportation
- CO$_2$ cost > $35/tonne can stress EOR economics
- CO$_2$ costs tied to price of oil
- Actual cost of CO$_2$ is confidential business information
Oil & Gas Field Sequestration Potential

EOR Potential: Rockies to Mississippi River
27.3 B bbls (Best Practice) to 39.5 B bbls (Next Gen)
61% to 79% of EOR resources
67% of favorable fields

EOR Potential: Illinois-Michigan-Appalachia
0.6 B bbls (Best Practice) to 2.1 B bbls (Next Gen)
1% to 4% of EOR resources
13% of favorable fields

EOR Potential: West of the Mississippi
32.7 B bbls (Best Practice) to 45.1 B bbls (Next Gen)
73% to 90% of EOR resources
76% of favorable fields

EOR Potential: Gulf Coast
2.2 B bbls (Best Practice) to 3.0B bbls (Next Gen)
5% to 6% of EOR resources
11% of favorable fields


ARI report for NETL: Storing CO₂ and Producing Domestic Crude Oil with Next Generation CO2-EOR Technology. Jan 2009
EPA Class VI Rules

• EPA UIC Class VI rules published in the Federal Register in December, 2011.
• These rules cover all of the items listed in Article 11A, §22-11A-4: General powers and duties of the secretary with respect to carbon dioxide sequestration.
• These rules cover most of the items listed Article 11A, §22-11A-5: Permit application requirements and contents; permit application fees.
  – Class VI rules not concerned with pore space ownership
  – Class VI rules do not discuss fees
  – Limited discussion on public review of application/permit; refer to 40 CFR §124.10
  – Class VI rules not concerned with overall field, permit tied to injection wells, not to field the entire field.
• This Working Group has discussed/recommended that West Virginia establish primacy for Class VI wells.
EPA Class VI Rules

• Class VI rules, though not prescriptive, are extensive.
• If you call it sequestration a Class VI permit is required.
• If you call it EOR a Class II permit is required
  – Provisions for converting Class II permits to Class VI
  – If Director considers EOR operations a risk to USDW can require conversion to Class VI
• Any well drilled during site characterization can not be converted to Class VI
  – These wells considered strat tests
  – Can be utilized as monitoring wells
• Class VI permit application requires:
  – Area of Review (AoR) and corrective action plan
  – Monitoring and testing plan
  – Injection well plugging plan
  – Post-Injection Site Care (PSIC) and site closure plant
  – Emergency and remedial response plan
EPA Class VI Rules

• Financial Responsibility required to get permit:
  – Corrective Action – remediation of existing wells
  – Injection Well Plugging
  – Post-Injection Site Care & Site Closure
  – Emergency & Remedial Response

• Financial instruments will be effective prior to operations
  – Trust Fund, Letters of Credit, Surety Bonds, Insurance, Escrow Account
  – Financial Test & Corporate Guarantees
    • Recommended owner/operator tangible net worth of $100 million
  – If EPA is “Director” then can’t be beneficiary of instruments, set-up stand-by trust
    • If state is “Director” is can be a beneficiary (?)
    • Primacy can increase control over financial responsibility funds (?)

• Beginning injection operations is a two-step process:
  – Apply for permit and get approval to drill Class VI injection well(s)
  – Incorporate data from drilling Class VI injection into AoR model and other relevant plans and present to Director
  – Receive final approval to begin injection operations
EPA Class VI Rules
Items not covered

- **Overall storage site & operations**
  - A site permit is included in this Working Group’s recommendations

- **Monitoring Wells**
  - Required by Class VI rules, number depends on approved plans
  - Permitted by state
  - Financial responsibility covered by PISC & site closure

- **Site characterization process**
  - An exploration effort for saline reservoirs
  - EPA assigns a 25% success factor
  - Play concept – assemble large acreage block, far more than needed
  - Permits needed during site characterization
EPA Class VI Rules
Items not covered

• Production of formation fluids
  – May be necessary to control reservoir pressure
  – May be necessary to control plume
  – Co-injection of water may increase storage efficiency
    • Use portion of produced waters, dispose or treat remainder
  – Another layer of operations
  – More permits: producing wells and water disposal wells
    • How to permit water disposal wells: Class I, II or V?
  – Increased capital and operating expenses
    • Potential for sales of treated (potable) water

• Other financial responsibilities to consider
  – Surface facilities
  – Other typical business coverage
EPA Class VI Rules
MVA

• Monitoring wells required (direct methods)
  – Above and into injection zone
  – Geochemistry, pressure

• Indirect methods
  – Seismic, electrical, gravity, electromagnetic

• Post-Injection monitoring
  – VSP and Cross-Well seismic
  – Electromagnetic surveys, electrical resistance tomography, microgravity surveys

• These technologies suggest locations from which to monitor the CO$_2$ plume
Questions