Objective and Focus of the Presentation

**Objective**
- Evaluate the Impact of Adding a Carbon Capture and Sequestration (CCS) Plant on the Site Selection Process of a New Power Plant

**Focus**
- Additional Considerations and Requirements Imposed by a CCS Plant on Top of the Standard Criteria for a Power Plant Without a CCS
### Power Plant Site Selection Criteria

- Land Availability or CCS Footprint
- Seismic Stability
- Floodplain
- Weather
- Existing Site Hazards
- Existing Land Use
- Restricted Air Space
- Cultural Resources
- Threatened and Endangered Species
- Proximity to Public Access Areas

### Power Plant Site Selection Criteria (cont’d)

- State/Local Environmental Requirements
- Proximity to Class I Visibility Areas
- Proximity to Tribal Lands
- Access to Cooling Water
- Fuel Supply Environment
- Access to Grid
- Rights of Way
- Transportation Options Available
- Labor and Skills Availability
- Cost and Economic Environment
Power Plant Site Selection Criteria (cont’d)

- **Focus Criteria**
  - Cooling Water Consumption & Availability
  - CO₂ Transportation and Storage
  - Land Availability & CCS Footprint
  - Labor and Skills Availability
  - Fuel Supply Consideration

Power Plant Site Selection Criteria
Cooling Water Consumption

- Majority of cooling water consumption are losses through cooling tower
  - Evaporation; blowdown; drift
- Additional water consumption is primarily due to additional power generation
  - A CCS plant reduces power generation for a fixed fuel input – steam diverted for CO₂ stripping
  - A CCS plant requires additional generation for a fixed electric output
## Cooling Water Consumption

<table>
<thead>
<tr>
<th></th>
<th>Without CO₂ Capture</th>
<th>With CO₂ Capture</th>
<th>With CO₂ Capture</th>
<th>With CO₂ Capture</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tons/Yr/MWe*</td>
<td>GPM/MWe</td>
<td>Tons/Yr/MWe*</td>
<td>GPM/MWe**</td>
</tr>
<tr>
<td>Natural Gas Combined Cycle</td>
<td>8,350</td>
<td>4.5</td>
<td>18,100</td>
<td>9.7</td>
</tr>
<tr>
<td>IGCC</td>
<td>11,640</td>
<td>6.3</td>
<td>15,340</td>
<td>8.2</td>
</tr>
<tr>
<td>Supercritical PC</td>
<td>18,440</td>
<td>9.9</td>
<td>41,480</td>
<td>22.2</td>
</tr>
</tbody>
</table>

* At 85% Capacity Factor

** Per Net MWe

## Cooling Water Cost

**Ultra-Supercritical PC Plant**

750 MWe w/o and with CO₂ Capture

<table>
<thead>
<tr>
<th></th>
<th>Unit Rate Per 1,000 Gallons</th>
<th>Annual Cost* Without CO₂ Capture</th>
<th>Annual Cost* With CO₂ Capture</th>
<th>Annual Incremental Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Large Body of Water</td>
<td>$0.38</td>
<td>$1.3 Million</td>
<td>$1.8 Million</td>
<td>$0.5 Million</td>
</tr>
<tr>
<td>Municipal (Average)</td>
<td>$2.50</td>
<td>$8.5 Million</td>
<td>$11.8 Million</td>
<td>$3.3 Million</td>
</tr>
<tr>
<td>Total O&amp;M Cost w/ fuel</td>
<td>$0.38</td>
<td>$186 Million</td>
<td>$246 Million</td>
<td>$60 Million</td>
</tr>
</tbody>
</table>

* At 85% Capacity Factor
Power Plant Site Selection Criteria

Cooling Water Consumption

- Impact of incremental cost of water is small:
  - Approx. 40% additional water cost over the non-CCS case
  - Approx. 0.8% additional O&M cost over the non-CCS case
- Availability (opposed to cost) of makeup water is a key issue in site selection

Power Plant Site Selection Criteria

Cost of CO₂ Pipeline Transport

- CO₂ transport system cost
  - 150 miles of pipeline
  - 50 million tons per year (equivalent to about 10 x 750 MWe PC plants)
  - 2,200 psia CO₂ pressure (determines pipe size)
  - Total cost – approx. $1.50 per ton transported
  - Approx. $7.5MM per plant-year
- Cost of CO₂ removed ~$225MM per plant-year
- Conclusion: Impact of CO₂ transport is small
Power Plant Site Selection Criteria
Cost of CO₂ Injection and MMV

<table>
<thead>
<tr>
<th></th>
<th>Depth 1,000 meters</th>
<th>Depth 2,000 meters</th>
<th>Depth 3,000 meters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Saline Aquifer</td>
<td>1.75 $/Ton</td>
<td>2.50</td>
<td>5.00</td>
</tr>
<tr>
<td>Cost to a Power Plant</td>
<td>$8.75MM/Plant-Yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Natural Gas or Oil Field</td>
<td>0.85 $/Ton</td>
<td>1.75</td>
<td>3.40</td>
</tr>
<tr>
<td>Cost to a Power Plant</td>
<td>4.25MM/Plant-Yr</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ocean Storage</td>
<td>5 $/Ton</td>
<td>Includes 150 miles on-shore &amp; 65 miles off-shore transportation</td>
<td></td>
</tr>
<tr>
<td>Cost to a Power Plant</td>
<td>25MM/Plant-Yr</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Storage cost could be significant depending on the type of storage

Land Availability
750 MWe USC PC Plant without CCS
Land Availability
750 MWe USC PC Plant with CCS

- Additional Space needed for a CCS facility (approx. 520,000 ft² – i.e., 12 acres)
- No additional land needed – same site boundary

Conclusion: Generally, land availability has negligible impact on site selection
Labor and Skills Availability
750 MWe USC PC Plant with CCS

- Addition of chemical plant at a power generation facility
  - May not be an issue for an IGCC plant
  - Will the needed skilled workers be available?
  - New or different union agreements; new permitting & reporting; health & safety requirements

- Conclusion: Availability of skilled workers will have a minor impact on site selection

Fuel Availability
750 MWe USC PC Plant with CCS

- Coal Consumption
  - 8,000 hours annual operation at full load
  - PRB sub-bituminous coal
  - Net efficiency: 38.4% w/o; 25.2% with CCS

- For 750 MWe Net Output for Both Cases:
  - 3.2 million tons per year without CO₂ capture
  - 4.9 million tons per year with CO₂ capture
  - 50% additional consumption

- Conclusion: Fuel Availability May be a Consideration
## Power Plant Site Selection Criteria
### Power Plant with CCS
#### Summary Conclusion

<table>
<thead>
<tr>
<th>Focus Criteria</th>
<th>Impact</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Cooling Water Consumption</td>
<td></td>
</tr>
<tr>
<td>- Availability</td>
<td>Availability is key</td>
</tr>
<tr>
<td>- Cost</td>
<td>&lt;1% to about 5% of incremental O&amp;M cost</td>
</tr>
<tr>
<td>- CO₂ Transportation</td>
<td>Approx. 3% of cost of CO₂ removed</td>
</tr>
<tr>
<td>- CO₂ Injection &amp; MMV</td>
<td>Approx. 2% to 4% of cost of CO₂ removed</td>
</tr>
<tr>
<td>- Land Availability &amp; CCS Footprint</td>
<td>Very Small</td>
</tr>
<tr>
<td>- Labor and Skills Availability</td>
<td>Very Small</td>
</tr>
<tr>
<td>- Fuel Supply Consideration</td>
<td>Could be Important</td>
</tr>
<tr>
<td></td>
<td>Requires 50% more fuel for the same net output</td>
</tr>
</tbody>
</table>