NATIONAL ENERGY TECHNOLOGY LABORATORY



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Modeling of the Costs of CCS for the Nation's Existing Coal-Fired Power Plant Reet

Presented for U.S. En January 2012

FOOL

Energy Association



Carbon Capture Model

• This work was funded by the U.S. DOE/NETL. Enegis would like to gratefully acknowledge their support and guidance

• The Rationale

- 50% of the nation's electric generation is from coal
- The fate of coal-fired generation is uncertain in a carbon-constrained world
- Overall goal is to develop cost/supply curves for retrofitting a scenario sample of the nation's fleet of CFPPs

• The Model

- Quantifies the cost and assess the feasibility of retrofitting the nation's fleet of coal-fired power plants (1088 Units, 332 GW)
- Uses the NETL study, Carbon Dioxide Capture from Existing Coal-Fired Power Plants, (Conesville Study) used as a foundation in terms of cost and layout
- Models costs based on cumulative examination of individual units
- Includes assessment of emissions for SOx and NOx



Modeling Mechanics







Sources of Information

- GIS Data Sources
 - Microsoft Terraserver—USA Imagery



Example showing typical image quality



Source: Microsoft Terraserver, Enegis, LLC, analysis

Sources of Information

- GIS Data Sources
 - Google Maps Imagery



Example Google Maps imagery (color) on a Terraserver Image Base





Carbon Capture Retrofit and Storage Modeling

Sources of Information

• Electricity Market Modules (EMMs)



Source: EIA, see http://www.eia.doe.gov/oiaf/aeo/assumption/electricity.html

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CAPEX

Investment CAPEX

- The CCM computes IC by the equation:
- (Letdown Turbine Cost + CO₂ Scrubber and Absorber Cost + FGD Cost + NOx Cost)

+

(CO₂ Separation and Compression Cost + Additional Cooling Cost)

+

Additional Land Cost



282 GW (738 Units)

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Primary FGD

- EPRI Study: Current Capital Cost and Cost-Effectiveness of Power Plant Emissions Control Technologies (January 2010)
- Wet and Dry FGD CAPEX Functions of Nameplate
- CCM Methodology
 - If No FGD then
 - Assume new Wet FGD Construction
 - Calculate Wet FGD CAPEX using Nameplate Function
 - If Wet or Dry FGD then
 - Assume no FGD CAPEX needed
 - FGD outlet concentration of 50 ppm



Sulfur Polishing

- Sulfur Polishing used for scrubbing after Primary FGD down to environmental target of 10 ppm
 - Requires calculation of the unit-specific tonnage of SO_X to be scrubbed by polishing
- CAPEX calculated as function of tonnage
 - \$94.57 /ton SO_X polished (NETL)



NOX/SCR

• EPRI Study: Current Capital Cost and Cost-Effectiveness of Power Plant Emissions Control Technologies (January 2010)

• SCR CAPEX Functions of Nameplate:

- If No SCR NO_X Control then
 - Calculate SCR CAPEX using Nameplate Function
- If SCR NO_X Control
 - Assume no CAPEX needed



 Based on the scenarios in the Conesville Study, calculated as the sum of:



Parasitic Load

• Computed as the Sum of the Parasitic Loads of:

- Newly installed NOx equipment
- Newly installed SO₂
 control equipment
- Additional cooling
- Parasitic steam for amine regeneration (212.91 kWh/tonne C0₂)
- CO₂ retrofit components



Physical Size and Cost Scaling

Physical Size and Cost Scaling



Required equipment geometries were digitized from the Conesville report so they could be scaled, relocated, and rotated to accommodate the remaining plants in the population



Construction Difficulty Factors

Two types of Construction Difficulty Factors

- Retrofit component conflict: More difficult engineering
 - E.g., conflict building letdown turbines, scrubbers, or compression field
 - Increase CAPEX by a scaled factor
 - Results of proprietary FGD construction difficulty study indicate CAPEX increases up to 200%
 - A separate factor will be used for each component and can be adjusted as a scenario
- Existing structure conflict: Component relocation
 - E.g., Railroad or substation
 - Increase CAPEX by a function of nameplate capacity as a relative portion of overall construction costs
- Retrofit component conflict cost impacts generally >> existing structure conflicts











Carbon Capture Retrofit and Storage Modeling **‹#**>





Graphical User Interface

| del Updates and Outpu | ts Model Parar | neters plate Header Name: | Avg Net Nameplate Capacity | w MW | Year Sample Choice | | | | |
|--|--|--|---|---|---|------------------------------|--|--|--|
| Output On Location Sh Output GEM Sheet | eet Query Heatra | ate Header Name: | Fully Loaded Tested Heat Rate Btu/kWh | | | | | | |
| COE Calculator Use Ph I LCOE Calcula Use PSFM LCOE Calcu LCOE Modifiers | tor Jator Modify P | Waxman-Markey Year: 2020 Modify Paths to Files Rath Variables (Files should be in Boot Directory of CCM Model) | | | | | | | |
| Incl. Carbon Allowance Incl. MUP Cost | e Cost Model Path | C:\CCM\Model\ | in hote bicably of cash mode | On Loca File 1 | On Location Input File Name: OnLoc CTS Costs xlsx | | | | |
| Sample Criteria Nameplate Cutoff Heatrate Cutoff Generation Cutoff Retirement Cutoff Emissions Control Federal Operators | Nameplate Option Min Unit Nameplate Max Unit Nameplate Min Plant Nameplate Max Plant Nameplate | Heatrate Optio Min Unit He Max Unit H Min Plant H Max Plant H | eatrate eatrate leatrate leatrate leatrate deatrate Generation Op Min Unit Ge Max Unit Ge Min Plant G Max Plant G | tion Min Unit N en en Sen Retirement Emission | ameplate Threshold (MW): Heatrate Threshold (Btu/kWh) Generation Threshold (GWh): Cutoff Minimum Year: S Control Option | 400 10000 2000 2025 | | | |
| NETL | Scenario Case Parameter CO2 Removal % (Low Cas CO2 Removal % (Medium CO2 Removal % (High Ca | s se) 90 C Case) 90 C se) 90 C | Capacity Factor (Low Case) Capacity Factor (Medium Case) Capacity Factor (High Case) | 65 Outp 75 € 85 | ut Units nglish Option (Ton) etric Option (Tonne) | | | | |

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Adders and Alternative Cost Structures Tab

| CAPEX Adders | | | | nar also constituineanes | | Include Water Availa | ability CAPEX Adders |
|--|--|---|--|--|--|--|--|
| Component Construction Diffic FGD (%): Letdown Turbines (%): Scrubbers and Absorbers (%): Cooling Towers (%): Compressor (%): | Low 25 25 25 25 25 25 25 25 | Medium 50 50 50 50 50 50 | High 200 200 200 200 200 200 | Structure Conflict Adders Plant Cost (\$/kW): Railroad Retrofit/Plant Cost (%): Coal Pile Retrofit/Plant Cost (%): Conveyors Retrofit/Plant Cost (%): Substation Retrofit/Plant Cost (%): | 1500 1 0.5 1 1 | Water Availability Add NERC Subregion Central MISO Gateway Delta | solity CAPEX Adders ers by NERC Subregion Cost Increase (%) 5 5 5 5 5 |
| Use Alternative Cost Structure Alternative Cost Structure Alternative Cost Structure Total CAPEX (%): Total CAPEX | | | | Use Alternative Parasitic Load Alternative Parasitic Load Parasitic Load (%): 100 | | SE ERCOT FRCC MRO | 5 5 5 5 |
| Component Cost Modifiers — Letdown Turbine CAPEX (%): Separation and Compression (Scrubbers and Absorbers CAP Additional Cooling CAPEX (%): Additional Primary FGD CAPE Additional SOX Polishing CAP Additional NOX CAPEX (%): | CAPEX (%): : : : : : : : : : : : : : : : : : : | () () () () () () () () () () () () () (| | | | NPCC - ISO NE NPCC - NY SERC - VACAR SPP - Northern SPP - Southern WSCC - AZNMSNV WSCC - CA WSCC - NWPP | 5 5 5 5 5 5 5 5 5 |
| | | | | | | WSCC - RMPA | 5 |

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GCM Phase II

Main Adders and Alternative Cost Structure



Scenario: ≥ 400 MW Unit Sample

- A model run was performed on the sample of units with a generation capacity of 400 MW and above
- Scenario CAPEX





Construction Cost Adders





Cumulative Structure Conflict Cost Adder Distribution





Scenario Carbon Capture and Storage Cost



Nameplate Capacity (MW)



≥ 400 MW Unit Sample

Scenario Incremental LCOE

235 GW (347 Units)



≥ 400 MW Unit Sample

Benefits/Uses

- Tailor analyses to examine an operator's portfolio of plants as a screening tool to assess the viability of retrofit
- Analyze electric generation/carbon-mitigation scenarios in a possible carbon-constrained world
 - Cumulative frequency cost/supply curves
 - Alternative CO₂ allowances
- Assess the costs of individual units and their components, including air emissions equipment
- Assess different alternative technology/situations for carbon capture and storage scenarios
- Model CFPP emission compliance costs relative to EPA Air Transport rule
- The Phase I Report can be found at: <u>http://www.netl.doe.gov/energy-analyses/refshelf/PubDetails.aspx?Action=View&Source=Main&PubId=289</u>





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