Scenario analysis of carbon capture and sequestration generation dispatch in the western U.S. electricity system

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Goals of this Presentation

• Explain dispatch model
• Demonstrate model capabilities
• Present example results
• Look for input on future scenarios from you
Motivation

• Limitations for CCS Deployment:
  ▪ Carbon sequestration sites are not ubiquitous
  ▪ Generation is highly dependant on transmission features

• Dispatch determines generator revenue and capacity factor

• Understand the economics and trade-offs of CCS sites to look for features of “good” CCS sites

Model – Software

• PowerWorld Simulator 13
  ▪ Calculates generation and load flows in electricity grid
  ▪ Commercial software
  ▪ Widely used in electricity industry

• Electricity Network Data
  ▪ Acquired from WECC (Western Electricity Coordinating Council) – some confidentiality
  ▪ Contains:
    ▪ 14 US States, 2 Canadian provinces, northern Baja California, Mexico
    ▪ Western Interconnection, CAISO, WESTCARB
Model – Data

• Electricity Network Data (cont.)

  ▪ 2,800 Generators of all types
  ▪ 58,000 mi. of transmission
  ▪ 190,000 MW of generation
  ▪ August 25, 2005 data

Model – Data (cont’d)

• Generator Data

  ▪ PowerWorld data contains no emissions data
  ▪ Matched with public data – EPA eGRID data
    • Also have WECC reports
  ▪ For most plants: fuel type, heat rate, emissions
  ▪ Cannot obtain: marginal cost / offer curves
    • Generator marginal costs are extremely confidential

  ▪ What we use: an approximation
    • Heat rate and fuel costs
    • Pollution costs of NOX and SOX
    • Also, cost of CO2 in scenarios
Model – Parameters

- Variable Parameters
  - Specific fuel costs
    - Coal, natural gas, oil
  - Non-dispatchable electricity costs
    - Hydro, nuclear, wind, solar, geothermal,
  - Pollution costs
  - Dispatch selection
    - Areas, specific plants
    - Fuels, types of plants
  - Load demand

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<thead>
<tr>
<th>Input Panel</th>
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<tr>
<td>(units)</td>
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<td>CO2 ($/tCO2)</td>
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<td>NOX ($/ton)</td>
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<td>SOX ($/ton)</td>
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<td>Coal ($/MWh)</td>
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<td>Oil ($/MMBtu)</td>
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<td>Natural Gas ($/MMBtu)</td>
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<td>Biomass ($/MWh)</td>
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<td>Other ($/MWh)</td>
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<td>Unknown ($/MWh)</td>
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Model – Limitations

- Limitations of Dispatch Model
  - Marginal cost dispatch
    - Dispatch does not account for CapEx
  - Not a levelized cost of electricity calculation
  - Imperfect proxy for capacity factor due to markets/contracts
  - Generator data is incomplete – especially marginal cost curves
    - Unless work for CAISO, will never be perfect
    - Future work will involve refinement of costs
  - Updates to grid (transmission, generation) not modeled
Scenario Assumptions

• Hypothetical IGCC-CCS Plants
  ▪ Note: considering Nth-of-the-kind
  ▪ Capacity: 500 MWe
  ▪ Heat rate: 11,000 Btu/kWh
  ▪ 100% capture
  ▪ Reminder: marginal dispatch, no capital costs

• Transmission
  ▪ Plants connected to largest, closest transmission substation
  ▪ Transmission connections are short (minimize losses)
  ▪ Transmission connections are large (no local congestion)

Results – Central Valley, California

• Gates Substation
  ▪ Note abrupt turn-on with demand level

• Pastoria Substation
  ▪ More gradual dispatch
  ▪ Location dependent!
Results – Burns Substation, Oregon

- Even more abrupt turn-on

![Burns Substation Map](image1.png)

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<th>Carbon Dioxide Price ($ per tCO2)</th>
<th>Generation (MW)</th>
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<tr>
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<td>200</td>
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- 70% load
- 75% load

Results – Nevada-California Border (Inyo Substation)

- Congestion limiting total plant dispatch
- Competing plants turning on

![Inyo Substation Map](image2.png)

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- 60% load
- 65% load
- 70% load
- 75% load
- 80% load
- 90% load
- 100% load
Results – Centralia, Washington (1528 MWe CCS Retrofit)

- Heat Rate: 15,000 Btu/kWh

Results – Pastoria Substation, California

- Note: Previous runs used $5/MMBtu Natural Gas
- Fuel price affects dispatch
Summary

- Model is up and validated
  - Able to perform a variety of calculations
- Results show in general – CCS will be dispatched given high enough carbon price and load demand/congestion
- Next steps: calculate capacity factors and plant revenue
- Looking to members of WESTCARB for ideas of other types of simulations

Future Work

- Ideas
  - More specific capacity factor calculations
    - 24-hour dispatches
    - Seasonal dispatches
    - Revenue and profitability calculations against COE
  - More locations
    - Ideas greatly appreciated here
  - Different kinds of plants
    - Retrofits, IGCC, SCPC, oxy-fired, etc.
    - Variable capture percentage plants
  - Coals
    - Illinois #6 vs. PRB?
Thank you!

Questions and Comments Welcome

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Appendix Slides
Scenario Assumptions

- Fuel Costs
  - Using August 25, 2005 data
    - slight modifications to validate case and model
    - issue – Hurricane Katrina
  - all generators face the same fuel costs
    - does not account for transportation or distribution cost
  - Coal (Powder River Basin): $1.42/MMBtu
  - Natural Gas: $5.00/MMBtu
  - NO\textsubscript{X}: $2,000/ton
  - SO\textsubscript{X}: $700/ton

Results – Four Corners, New Mexico
Results – Midway Substation, California

- Generation (MW) vs. Carbon Dioxide Price ($/tCO₂)
- Load scenarios: 60%, 65%, 70%

Results – Gates Substation, California

- Generation (MW) vs. Carbon Price ($/ton CO₂)
- Demand Load scenarios: 50%, 60%

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Results – Pastoria Substation, California (cont’d)

Model – Software

- PowerWorld Simulator 13
  - Calculates generation and load flows in electricity grid
  - Commercial software
  - Widely used in electricity industry

- Optimal Power Flow (OPF)
  - Takes transmission constraints into account
  - Used in our model

- Security-Constrained Optimal Power Flow (SCOPF)
  - Accounts for N-1 contingencies
  - Data currently unavailable