Onshore Lower 48 Oil & Gas Supply Submodule (OLOGSS)

Workshop
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Overview

• OLOGSS methodology overview

• OLOGSS Resources: Oil and Gas

• Enhanced oil recovery

• Shale gas
Interaction of OLOGSS with NEMS

NEMS

Exogenous Input
Drilling, Price, Supply, Reserves

OGSM

Domestic

Foreign

Onshore

The new “OLOGSS”

Offshore

Alaska

Oil

Gas

Known Fields
- Conventional
- Unconventional

Undiscovered
- Conventional
- Unconventional

Known Fields
- Conventional
- Unconventional

Undiscovered
- Conventional
- Unconventional

PMM

Oil Production
Wellhead Price
Parameter Estimate

OGSM Supply Functions

NGTDM
Gas Production Function
Role OLOGSS within NEMS

• Projects future domestic oil & gas supply
  - production from existing fields/reservoirs
  - reserves growth in existing fields/reservoirs
  - exploration in undiscovered fields/reservoirs

• Development of resources is subject to the following constraints
  - access to resource
  - technology
  - economics
  - infrastructure
    • drilling
    • CO$_2$ availability
    • pipeline
    • others
Capabilities of OLOGSS

- Model entire oil & gas resource in Lower 48
  - conventional
  - unconventional
    - tight sands
    - gas shale
    - coalbed methane

- Ability to model
  - technology change / improvements
  - land access issues
  - legislative policy issues (royalty relief, tax credits, etc…)

- Ability to address more policy and financial issues that affect the profitability of oil and natural gas drilling than with current module
Three phases of future production

• **Existing production**
  – from currently producing oil & gas fields

• **Reserves growth**
  – ASR / EOR
  – infill drilling

• **Undiscovered resource**
## Processes modeled

<table>
<thead>
<tr>
<th>Crude oil</th>
<th>Natural gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Water flooding</td>
<td>• Conventional/water drive</td>
</tr>
<tr>
<td>• Polymer flooding</td>
<td>• Tight gas</td>
</tr>
<tr>
<td>• Steam flooding</td>
<td>• Coalbed methane</td>
</tr>
<tr>
<td>• CO$_2$ flooding</td>
<td>• Shale gas</td>
</tr>
<tr>
<td>• Infill drilling</td>
<td></td>
</tr>
<tr>
<td>• Profile modification</td>
<td></td>
</tr>
<tr>
<td>• Horizontal drilling</td>
<td></td>
</tr>
</tbody>
</table>

- Crude oil: Water flooding, Polymer flooding, Steam flooding, CO$_2$ flooding, Infill drilling, Profile modification, Horizontal drilling
- Natural gas: Conventional/water drive, Tight gas, Coalbed methane, Shale gas
Primary model levers

• Technology levers
  – value of all levers
  – implementation & market penetration curves
  – interaction of technologies

• Economic levers
  – ROR
  – Risk

• Resource access parameters
OLOGSS overview

Input Data

Undiscovered

Exploration – Discovery Order

Exploration Economics

Discovered

Development – Production Decline Curve

Eligible for Secondary/Tertiary?

yes

Secondary/Tertiary Recovery Analysis

Economics

Project Ranking

Timing/Selection

Aggregation

Inputs to other Models

Reports
Resource development constraints

• Constraints will be used for future development of various resources
  – drilling
    • number of rigs
    • depth rating
  – capital constraints
    • E&P capital
    • others
  – co₂ availability – natural and industrial sources
  – access to land – federal/state
  – natural gas demand
  – others to be defined
Oil and gas resources in OLOGSS
37,000 oil and gas reservoirs

18,827 Oil Reservoirs
- Discovered: 12,741
- Undiscovered: 6,086

18,158 Gas Reservoirs
- Discovered: 11,271
- Undiscovered: 6,887

114 Billion Barrels of Oil
- 51 Billion Barrels
- 50 Billion Barrels
- 13 Billion Barrels

1,807 Tcf of Gas
- 1,337 Tcf
- 265 Tcf
- 205 Tcf
Categories of oil reservoirs in OLOGSS

Reservoirs Can be Candidates for Several EOR/ASR Processes
Enhanced oil recovery

• Resources
  – CO₂ Flooding
  – Steam Flooding
  – Polymer Flooding
  – Profile Modification

• AEO2011 production projections

• CO₂ EOR sensitivities
Technical production for EOR/ASR

billion barrels

<table>
<thead>
<tr>
<th>Method</th>
<th>Production</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO2 EOR</td>
<td>40 billion</td>
</tr>
<tr>
<td>Steam Flood</td>
<td>7 billion</td>
</tr>
<tr>
<td>Polymer</td>
<td>12 billion</td>
</tr>
<tr>
<td>Infill</td>
<td>7 billion</td>
</tr>
</tbody>
</table>
| Profile Modification  | 5 billion  | (Vertical & Horizontal)
Technical and economic production for EOR/ASR

-billion barrels-

<table>
<thead>
<tr>
<th>Method</th>
<th>Technical</th>
<th>$50/Bbl</th>
<th>$80/Bbl</th>
<th>$125/Bbl</th>
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</thead>
<tbody>
<tr>
<td>CO2 EOR</td>
<td>40</td>
<td>15</td>
<td>10</td>
<td>5</td>
</tr>
<tr>
<td>Steam Flood</td>
<td>10</td>
<td>7</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Polymer</td>
<td>10</td>
<td>7</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Infill</td>
<td>10</td>
<td>7</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>Profile Modification</td>
<td>10</td>
<td>7</td>
<td>5</td>
<td>3</td>
</tr>
</tbody>
</table>

Technical and economic production for EOR/ASR.
Onshore crude oil production - reference case

Source: EIA Annual Energy Outlook 2011
Components of EOR/ASR production - reference case

million barrels per day

Source: EIA Annual Energy Outlook 2011
Total EOR production

$million \text{ barrels per day}$

Source: EIA Annual Energy Outlook 2011
### Oil fields currently employing CO\textsubscript{2} EOR

<table>
<thead>
<tr>
<th>Category</th>
<th>Field Count</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active</td>
<td>113</td>
</tr>
<tr>
<td>Planned</td>
<td>12</td>
</tr>
<tr>
<td>Candidates</td>
<td>2,235</td>
</tr>
</tbody>
</table>

**Map of Oil Fields**

- **Existing Oil Fields**
- **Planned Oil Fields**
- **Candidate Oil Fields**
Sources of CO$_2$

• Natural

• Anthropogenic
  – Hydrogen Plants
  – Ammonia Plants
  – Ethanol Plants
  – Cement Plants
  – Refineries
  – Power Plants
  – Natural Gas Processing Plants
  – Coal-to-liquids Plants
## CO₂ availability assumption

<table>
<thead>
<tr>
<th>Source Type</th>
<th>Infrastructure Development (years)</th>
<th>Market Acceptance (years)</th>
<th>Ultimate Market Acceptance</th>
<th>Maximum CO₂ Volumes (million tons)</th>
<th>Average Carbon Capture &amp; Transportation (within Region) Cost ($/ton)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ammonia Plants</td>
<td>2</td>
<td>10</td>
<td>100%</td>
<td>4.5</td>
<td>31</td>
</tr>
<tr>
<td>Natural Gas Processing</td>
<td>2</td>
<td>10</td>
<td>100%</td>
<td>10.9</td>
<td>27</td>
</tr>
<tr>
<td>Ethanol Plants</td>
<td>4</td>
<td>10</td>
<td>100%</td>
<td>18.4</td>
<td>33</td>
</tr>
<tr>
<td>Hydrogen Plants</td>
<td>4</td>
<td>10</td>
<td>100%</td>
<td>0.2</td>
<td>37</td>
</tr>
<tr>
<td>Refineries</td>
<td>4</td>
<td>10</td>
<td>100%</td>
<td>16.7</td>
<td>29</td>
</tr>
<tr>
<td>Cement Plants</td>
<td>7</td>
<td>10</td>
<td>100%</td>
<td>21.6</td>
<td>70</td>
</tr>
<tr>
<td>Fossil Fuel Plants</td>
<td>12</td>
<td>10</td>
<td>100%</td>
<td>1,209.0</td>
<td>100</td>
</tr>
<tr>
<td>Coal-to-Liquids</td>
<td>Determined by the Petroleum Market Module</td>
<td></td>
<td>77.2</td>
<td>27</td>
<td></td>
</tr>
</tbody>
</table>
CO$_2$ EOR production

million barrels per day

Source: EIA Annual Energy Outlook 2011
Alternative cases

• Reference case
  – no CO\textsubscript{2} tax
  – high proportion of high purity industrial CO\textsubscript{2} streams can be purchased by oil producers

• Carbon Policy case
  – CO\textsubscript{2} tax: rises from $25/ton in 2013 to $77/ton in 2035
  – oil producers receive CO\textsubscript{2} at reduced rates as quantity captured increases

• Reduced CO\textsubscript{2} cases
  – reduction in amount of anthropogenic CO\textsubscript{2} available to oil producers

• Reduced CO\textsubscript{2} with Carbon Policy case
  – same carbon tax as in Carbon Policy case
CO₂ EOR production

*million barrels per day*

- Reference case
- Carbon policy case
- Reduced CO₂ case
- Reduced CO₂ with policy case

Source: EIA Annual Energy Outlook 2011
Natural gas projections in OLOGSS

- OLOGSS Gas Resources
- Components of Projections
- Shale Gas Analysis
Gas reservoirs by classification

- **Decline Gas**: 11,271 reservoirs
- **Conventional**: 5,882 reservoirs
- **Shale**: 307 reservoirs
- **Tight**: 43 reservoirs
- **CBM**: 655 reservoirs

Undiscovered Gas Reservoirs
Technical production for natural gas

trillion cubic feet

Conventional  Shale  Tight  Coalbed Methane

[Bar chart showing the technical production for different types of natural gas: Conventional, Shale, Tight, Coalbed Methane.]
Technical and economic production for natural gas

- Conventional
- Shale
- Tight
- Coalbed Methane

trillion cubic feet

- Technical
- $4/Mcf
- $6/Mcf
- $10/Mcf
Shale gas

- Uncertainties
- Resource assumptions
- Sensitivities
Shale gas uncertainties

- Considerable shale play/formation heterogeneity
- Shale productive capability is largely untested
- Long-term decline and recovery rates are unknown
- Producers maximize rates of return (ROR), not resource recovery
- Recovery rates depend on gas prices and production costs
- Re-fracturing potential is unknown
- Public information bias creates expectations that overstate “typical” shale gas well recovery and profitability
Within a shale formation, the following attributes will vary:

- Depth
- Formation thickness
- Pore space
- Pore pressure
- Carbon content → absorbed gas
- Thermal maturity
- Clay content (more clay → shorter fracture length and/or higher fracturing cost)
## Lower 48 technically recoverable unproved shale gas resources

### trillion cubic feet

<table>
<thead>
<tr>
<th>Region</th>
<th>AEO2011</th>
<th>AEO2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast</td>
<td>473</td>
<td>73</td>
</tr>
<tr>
<td>Gulf Coast</td>
<td>105</td>
<td>90</td>
</tr>
<tr>
<td>Midcontinent</td>
<td>63</td>
<td>51</td>
</tr>
<tr>
<td>Southwest</td>
<td>87</td>
<td>60</td>
</tr>
<tr>
<td>Rocky Mountain</td>
<td>58</td>
<td>22</td>
</tr>
<tr>
<td>West Coast</td>
<td>41</td>
<td>51</td>
</tr>
<tr>
<td><strong>Lower 48 Total</strong></td>
<td><strong>827</strong></td>
<td><strong>347</strong></td>
</tr>
</tbody>
</table>
### Technically recoverable unproved shale gas resources

**billion cubic feet**

<table>
<thead>
<tr>
<th>Region</th>
<th>Basin</th>
<th>Play</th>
<th>AEO2011</th>
<th>AEO2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Northeast</td>
<td>Appalachian</td>
<td>Marcellus – Developing</td>
<td>177,931</td>
<td>47,504</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Marcellus – Undeveloped</td>
<td>232,443</td>
<td>--</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Devonian - Big Sandy Central</td>
<td>6,490</td>
<td>3,428</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Devonian - Big Sandy Extension</td>
<td>940</td>
<td>2,247</td>
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<tr>
<td></td>
<td></td>
<td>Devonian - Greater Siltstone</td>
<td>8,463</td>
<td>2,133</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Devonian - Low Thermal Maturity</td>
<td>13,534</td>
<td>4,015</td>
</tr>
<tr>
<td>Illinois</td>
<td></td>
<td>Devonian - Cincinnati Arch</td>
<td>1,435</td>
<td>1,106</td>
</tr>
<tr>
<td>Michigan</td>
<td></td>
<td>New Albany</td>
<td>10,947</td>
<td>2,998</td>
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<tr>
<td></td>
<td></td>
<td>Antrim</td>
<td>20,512</td>
<td>9,738</td>
</tr>
<tr>
<td>Gulf Coast</td>
<td>TX-LA-MS Salt</td>
<td>Haynesville</td>
<td>80,023</td>
<td>71,974</td>
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<tr>
<td></td>
<td>Western Gulf Coast</td>
<td>Eagle Ford</td>
<td>20,807</td>
<td>18,344</td>
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<tr>
<td></td>
<td>Black Warrior</td>
<td>Floyd-Neal/Conasauga</td>
<td>4,465</td>
<td>--</td>
</tr>
<tr>
<td>Midcontinent</td>
<td>Arkoma</td>
<td>Fayetteville – Central</td>
<td>29,505</td>
<td>26,056</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fayetteville – West</td>
<td>4,639</td>
<td>3,476</td>
</tr>
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<td></td>
<td>Anadarko</td>
<td>Woodford – Western</td>
<td>19,771</td>
<td>15,503</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Woodford – Central</td>
<td>8,664</td>
<td>5,945</td>
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<tr>
<td>Southwest</td>
<td>Fort Worth</td>
<td>Barnett – Core</td>
<td>34,923</td>
<td>29,454</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Barnett – Extension</td>
<td>19,732</td>
<td>16,399</td>
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<tr>
<td></td>
<td>Permian</td>
<td>Barnett-Woodford</td>
<td>32,152</td>
<td>13,690</td>
</tr>
<tr>
<td>Rocky Mountain</td>
<td>Greater Green River</td>
<td>Hilliard-Baxter-Mancos</td>
<td>3,770</td>
<td>--</td>
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<tr>
<td></td>
<td>San Juan</td>
<td>Lewis</td>
<td>11,638</td>
<td>17,790</td>
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<tr>
<td></td>
<td>Uinta</td>
<td>Mancos</td>
<td>21,021</td>
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<td></td>
<td>Williston</td>
<td>Shallow Niobrara</td>
<td>6,757</td>
<td>3,831</td>
</tr>
<tr>
<td></td>
<td>Undiscovered</td>
<td></td>
<td>14,626</td>
<td>--</td>
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<tr>
<td>West Coast</td>
<td>Undiscovered</td>
<td></td>
<td>41,356</td>
<td>50,870</td>
</tr>
</tbody>
</table>
U.S. Geological Survey (USGS) shale gas resource assessment uncertainty

Summary statistics for the 20 USGS shale assessment units:

**F95/mean natural gas volume ratio:**

- Arithmetic average = 51 percent
- Gas volume weighted average = 58 percent

**F5/mean natural gas volume ratio:**

- Arithmetic average = 164 percent
- Gas volume weighted average = 153 percent

USGS resource estimate range supports the +/- 50 percent shale gas case variance.
AEO2011 shale gas resource determinants

The key determinants of the AEO2011 technically recoverable shale gas resource base are:

(1) the estimated ultimately recovery (EUR) per well, and

(2) the formation acreage from which natural gas can be produced.

Shale gas cases were created by varying the reference case resource EUR and recovery factors by +/- 50%, which is consistent with USGS 95 and 5 percent probability range.

Shale cases are meant to be illustrative of the shale gas resource uncertainty and do not represent confidence intervals or expected probability distributions.
High shale gas cases

- **High EUR case.** The estimated ultimately recovery (EUR) per shale gas well is assumed to be 50 percent higher than in the AEO2011 Reference case. Well spacing remains unchanged. Each well is recovering 50% more gas from the same acreage. The formation’s productive acreage remains unchanged.

- **High Recovery case.** Fifty percent (50%) more natural gas can be recovered from the shale formation than in the Reference case, with 50 percent more productive acreage. The EUR per well is unchanged. Fifty percent (50%) more wells would be drilled to fully recover the shale gas in each play.

- In both cases, the technically recoverable **unproved** shale gas resource potential increases from 827 Tcf to 1,230 Tcf.
Low shale gas cases

- **Low EUR case.** The estimated ultimately recovery (EUR) per shale gas well is assumed to be 50 percent lower than in the AEO2011 Reference case. Well spacing remains unchanged. Each well is recovering 50% less gas from the same acreage. The formation’s productive acreage remains unchanged.

- **Low Recovery case.** Fifty percent (50%) less natural gas can be recovered from the shale formation than in the Reference case, with 50 percent less productive acreage. The EUR per well is unchanged. Fifty percent (50%) less wells would be drilled to fully recover the shale gas in each play.

- In both cases, the technically recoverable unproved shale gas resource potential decreases from 827 Tcf to 423 Tcf.
Implications of shale gas cases

• **High/Low EUR cases** vary the cost of producing shale gas on a per unit basis by varying the volume of gas that can be recovered from a well at a fixed capital cost per well. These cases exhibit the greatest variability in gas prices, consumption, and supply.

• **High/Low recovery cases** vary the area of the shale gas resource endowment, but do not affect the cost of producing gas within the productive area. Gas prices increase as the less expensive shale gas formations are depleted first. These cases exhibit less variability in gas prices, consumption, and supply.
Shale gas production

Source: EIA Annual Energy Outlook 2011
Total natural gas production

 trillion cubic feet per year

Source: EIA Annual Energy Outlook 2011
Henry Hub spot natural gas prices

dollars per million Btu in 2009 constant dollars

Source: EIA Annual Energy Outlook 2011

Reference case
High EUR
Low EUR
High Recovery
Low Recovery

Source: EIA Annual Energy Outlook 2011
For more information


Annual Energy Outlook 2011 | www.eia.gov/aeo

Short-Term Energy Outlook | www.eia.gov/steo

Oil and Gas Supply Module Documentation | www.eia.gov/analysis/model-documentation.cfm

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