Onshore Lower 48 Oil & Gas Supply Submodule

Methodology Peer Review

December 6 – 7, 2006
Vienna, VA
<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Presenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>8:30-8:45 AM</td>
<td>Welcoming Remarks</td>
<td>Dana Van Wagener/Philip Budzik</td>
</tr>
<tr>
<td>8:45-9:15</td>
<td>Overview of NEMS</td>
<td>Dana Van Wagener/Philip Budzik</td>
</tr>
<tr>
<td></td>
<td>Reason for New Model</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Expectation of Peer Review</td>
<td></td>
</tr>
<tr>
<td></td>
<td>New NEM Design</td>
<td></td>
</tr>
<tr>
<td>9:15-10:15</td>
<td>Overall System Logic</td>
<td>INTEK, Inc./Serco</td>
</tr>
<tr>
<td></td>
<td>Logic Flow</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Envisioned Product</td>
<td></td>
</tr>
<tr>
<td></td>
<td>New Enhancements</td>
<td></td>
</tr>
<tr>
<td>10:15-10:30</td>
<td>Coffee Break</td>
<td>---------------------------</td>
</tr>
<tr>
<td>10:30-11:30</td>
<td>Resource Module</td>
<td>INTEK, Inc./Serco</td>
</tr>
<tr>
<td></td>
<td>Data Description &amp; Sources</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Discovered</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Undiscovered</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Production</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Reserves</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Future Updates</td>
<td></td>
</tr>
<tr>
<td>11:30-12:00</td>
<td>Technology Screening Module</td>
<td>INTEK, Inc/Serco</td>
</tr>
</tbody>
</table>
# Peer Review Agenda

**Wednesday, December 6, 2006**

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Presenter</th>
</tr>
</thead>
<tbody>
<tr>
<td>12:00-1:00 PM</td>
<td>Lunch</td>
<td></td>
</tr>
<tr>
<td>1:00-1:45</td>
<td>Process Module</td>
<td>INTEK, Inc./Serco</td>
</tr>
<tr>
<td></td>
<td>- Type Curves</td>
<td></td>
</tr>
<tr>
<td>1:45-2:45</td>
<td>Technology Levers/User Options</td>
<td>INTEK, Inc./Serco</td>
</tr>
<tr>
<td>2:45-3:00</td>
<td>Coffee Break</td>
<td></td>
</tr>
<tr>
<td>3:00-5:00</td>
<td>Economic Module</td>
<td>INTEK, Inc./Serco</td>
</tr>
<tr>
<td></td>
<td>- Model Description/Logic Flow</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Economics</td>
<td></td>
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<tr>
<td></td>
<td>- Ranking of Projects</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Selection of Projects</td>
<td></td>
</tr>
<tr>
<td>Time</td>
<td>Topic</td>
<td>Presenter</td>
</tr>
<tr>
<td>-------------------</td>
<td>-----------------------------------------------</td>
<td>--------------------</td>
</tr>
<tr>
<td>8:30-10:15 AM</td>
<td>Development Economic &amp; Constraints</td>
<td>INTEK, Inc./Serco</td>
</tr>
<tr>
<td>10:15-10:30</td>
<td>Coffee Break</td>
<td></td>
</tr>
<tr>
<td>10:30-11:30</td>
<td>Open Discussions</td>
<td>All</td>
</tr>
<tr>
<td>11:30-12:00</td>
<td>Summary of Comments &amp; Concluding Remarks</td>
<td>INTEK, Inc./Serco</td>
</tr>
<tr>
<td>12:15 PM</td>
<td>Meeting Adjourned</td>
<td>Dana Van Wagener</td>
</tr>
</tbody>
</table>
Overview of NEMS

Dana Van Wagener
Oil and Gas Modeling Specialist
Energy Information Administration
US Department of Energy
NEMS Overview

- Functional model for many analytical needs
- Extensively developed and adapted to maintain relevancy beyond simple updates and periodic extensions of the forecast horizon
- Unnecessary and impractical to start from scratch
NEMS Redesign

• Initial outreach efforts

• Interest varies throughout DOE

• General Feedback
  ➢ Extend the horizon to 2050 or later
  ➢ Add significant technological and program detail
  ➢ Enhance integration of U.S. energy markets with both the macro economy and world markets
  ➢ Add representations of energy infrastructure
  ➢ Drill down dynamically to more regional detail
  ➢ Add uncertainty analysis and stochastic scenarios
  ➢ Add automatic diagnostics
  ➢ Add transparency
  ➢ And … by the way, solve in less than one hour
NEMS – Next Steps

- Expect further discussions with DOE and external stakeholders on projects and priorities
- Initiated testing of alternative optimization software
- Initiated review and redesign of several NEMS modules in FY06 and proposed for FY07
- Expect to initiate review on technology choice by sector and foresight used in consumer decision making in the Spring of 2007
- Additional module reviews to be done in priority order and as funds become available
OGSM Overview

 OGSM

 Domestic Oil & Gas Supply

 Lower 48 Onshore Conventional
 Unconventional Gas Recovery
 Oil Shale (Syncrude)
 Lower 48 Offshore Conventional
 Alaska

 Foreign Natural Gas Supply

 Canada
 Mexico

 OLOGSS
Characteristics of the Proposed Onshore component of OGSM

• Capability to address more policy and financial issues that affect the profitability of oil and natural gas drilling

• More technology levers

• Easy to maintain & update

• Fast execution time
Purpose of Peer Review

• Solicit input on modeling and analytic issues related to onshore oil and natural gas supply

• Identify/discuss limitations of proposed methodology

• Evaluate/discuss issues raised by the peer review panel
Onshore Lower 48 Oil & Gas Supply Submodule

Methodology Peer Review

December 6 – 7, 2006
Vienna, VA
Onshore Lower 48 Oil & Gas Supply Submodule

System Overview
Agenda

- Goal of OLOGSS
- OLOGSS Interaction with NEMS
- Overall System Logic
- Capabilities
Goal of OLOGSS

- To forecast Oil & Gas supply from Lower 48 Onshore
- Existing Fields/Reservoirs
- New Discoveries
- Reserves Growth
  - EOR / ASR
  - Improved Technology
Interaction of OLOGSS with NEMS

NEMS

OGSM

Domestic

Foreign

Onshore

Offshore

Alaska

The new "OLOGSS"

Oil

Gas

Known Fields
- Conventional
- Unconventional

Undiscovered
- Conventional
- Unconventional

Known Fields
- Conventional
- Unconventional

Undiscovered
- Conventional
- Unconventional

Exogenous Input
Drilling, Price, Supply, Reserves

Oil Production

Wellhead Price

Parameter Estimate

NEMS

Oil Production Wellhead Price

Parameter Estimate

OGSM

Supply Functions

PMM

NGTDM
Gas Production Function

INTEK
Overall System Logic Flow

- Master Database
- Resource Description Module
- Process Module
- Economic/Timing Module
- Reports

Model Option Files

Other Input
- Costs
- Fiscal Data

Highlights
- Plug and Play
- Modular
- User Friendly

INTEK
Overall System Logic Flow

- “Data Warehouse” - Master Database of Oil and Gas Resources in Lower 48 Onshore
  - Discovered (NRG Associates, HPDI, etc)
  - Undiscovered (USGS, MMS)
  - Secondary Sources (COGAM, EIA, Others)
Overall System Logic Flow

- Master Database
- Resource Description Module

- Compiles Raw Data to Create Input Files For Use in the Model
- Check for Quality, Consistency, Completeness
- Aggregate and Process Data Based on “Unit of Analysis”
- Allocate Resources per OLOGSS Regions
Proposed OLOGSS Regions

Original Onshore OGSM Regions

New OLOGSS Regions

INTEK
Overall System Logic Flow

- Master Database
- Resource Description Module
- Process Module

- Estimates Production Profile for Each Resource Type Based on Production Profile Functions
- Screens Technically Viable Process for Each Resource
Overall System Logic Flow

Master Database

Resource Description Module

Process Module

Model Option Files

User defined
- Resource Development Constraints
- Technology Options/ Levers
- Economic Options/ Levers
- Resource Access Parameters
Overall System Logic Flow

- Master Database
- Resource Description Module
- Process Module
- Economic/Timing Module

Model Option Files

Performs Economic Evaluation and Timing of Oil and Gas Resources
- Discovered and Undiscovered
- Rank and Select Resources based on Constraints
- Provides Supply Curves for NEMS
Overall System Logic Flow

Master Database

Resource Description Module

Process Module

Economic/Timing Module

Reports

Other Input
- Costs
- Fiscal Data

Model Option Files

- Production and Reserves
- Wells – Active and Drilled
- Economic results
- Aggregated at:
  - Play
  - Basin
  - State/Regional
  - National
Capabilities of Proposed OLOGSS

- Model Entire Oil & Gas Resource in Lower 48
  - Conventional
  - Unconventional
    - Tight Sand
    - Oil Shale
    - Continuous Formations, etc
- Ability to Model
  - Technology Change / Improvements
  - Land Access Issues
  - Legislative Policy Issues (Royalty Relief, Tax Credits, etc…)
- Easy to Maintain and Update
Onshore Lower 48 Oil & Gas Supply Submodule

Master Database & Resource Module
Agenda

• Goal and Objective
• Description of the Master Database
• Description of the Resource Module
• Unit of Analysis
Goal and Objective

- To Process Raw Data for Use in the Process and Timing Modules

- Resource Data has:
  - Enough Checks & Balances for Quality Control
  - Internally Consistent
  - Complete with no Missing Values
  - All Resources are Accounted
Overall System Logic Flow

- "Data Warehouse" - Master Database of Oil and Gas Resources in Lower 48 Onshore
  - Discovered (NRG Associates, EIA, HPDI, etc)
  - Undiscovered (USGS, MMS)
  - Secondary Sources (COGAM, EIA, Others)
### Summary of Sources of Resource Data

<table>
<thead>
<tr>
<th>Required Data</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Production Data</td>
<td>HPDI, EIA</td>
</tr>
<tr>
<td>Field/Reservoir Properties</td>
<td>NRG data *</td>
</tr>
<tr>
<td>Undiscovered Resource Estimates</td>
<td>USGS, MMS</td>
</tr>
<tr>
<td>Regional/Play Level Reserves Estimates</td>
<td>EIA</td>
</tr>
</tbody>
</table>

* Supplemented by COGAM Databases
Overall System Logic Flow

Master Database

Resource Description Module

- Compiles Raw Data to Create Input Files For Use in the Model
- Check for Quality, Consistency, Completeness
- Aggregate and Process Data Based on “Unit of Analysis”
- Allocate Resources per OLOGSS Regions
What is the Unit of Analysis

- Well (W)?
- Cell (C)?
- Reservoir (R)?
- Field (F)?
- Play (P)
- Basin (B)?
- State (S)?
- Region (Rg)?
Important Definitions

- **Reservoir**: Occurrence of Reservoir Rocks of Sufficient Quantity and Quality to Permit the Containment of Oil and Gas in Volumes Sufficient for an Accumulation of the Minimum Size

- **Field**: An Individual Producing Unit Consisting of a Single Pool or Multiple Pools of Hydrocarbons Grouped on, or Related to, a Single Structural or Stratigraphic Feature

- **Accumulation**: An Accumulation is Defined by the USGS as a Discrete Field or Pool of Hydrocarbon Localized in a Structural or Stratigraphic Trap by The Buoyancy of Oil or Gas in Water

- **Cell**: A cell is a quarter of a square mile of land surface in continuous formations. These are coded by USGS as predominantly oil producing, gas producing, both oil and gas producing or dry. The resource in each cell is characterized by its estimated ultimate recovery based on geologic characteristics of the continuous formation/accumulation

- **Play**: A play is defined as a set of known or postulated oil and/or gas accumulations sharing similar geologic, geographic, and temporal properties, such as source rock, migration pathways, timing, trapping mechanism, and hydrocarbon type.
Unit of Analysis
Is
Resource Specific
## Proposed Unit of Analysis

<table>
<thead>
<tr>
<th>Resource Type</th>
<th>Sources of Data</th>
<th>Unit of Analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Discovered</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Oil Conventional</td>
<td>NRG</td>
<td>Well Aggregated to Play Level</td>
</tr>
<tr>
<td>Oil Unconventional</td>
<td>HPDI / IHS</td>
<td></td>
</tr>
<tr>
<td>Gas Conventional</td>
<td>EIA</td>
<td></td>
</tr>
<tr>
<td>Gas Unconventional</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Undiscovered</strong></td>
<td>USGS Reserves Estimates</td>
<td>Conventional: Accumulation</td>
</tr>
<tr>
<td>Oil Conventional</td>
<td>MMS</td>
<td>Unconventional - Cells</td>
</tr>
<tr>
<td>Oil Unconventional</td>
<td>Play Level Properties (NRG)</td>
<td>Aggregated to Play Level</td>
</tr>
<tr>
<td>Gas Conventional</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gas Unconventional</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Role of Resource Description Module

- Defining the Play Level Resource Estimates
  - Both Oil & Gas
  - Both Discovered & Undiscovered

- Identifying the Number of Wells for Each Play (Active)

- Assigning Average Geologic Properties to Each Play/Well

- Creating the Play/Resource Specific Data Files
Resource Description Module Flowchart

Master Database

Discovered
- Calculate Average Well Production Profile For Field
- Assign Field Level Properties to Each Well
- Calculate Average Properties for a Play
- Aggregate Production at Play Level
- Define Bins

Undiscovered
- Define Resource Estimates Using USGS
- Assign Play Level Properties to Each Accumulation/Cell

Generate Resource Files
Discovered Resources – Define Well Profile

- Map NRG Database to EIA database using a crosswalk table
- Calculate average well production profile for each active well
- Assign reservoir properties to each well
### Reservoir/Field Properties Used for Analysis

<table>
<thead>
<tr>
<th><strong>Original Volumetrics</strong></th>
<th><strong>Geologic Data</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Original-Oil-In-Place</td>
<td>• Lithology</td>
</tr>
<tr>
<td>• Reservoir Area</td>
<td>• Depth</td>
</tr>
<tr>
<td>• Net Thickness</td>
<td>• Temperature</td>
</tr>
<tr>
<td>• Porosity</td>
<td>• Original and Current Pressure</td>
</tr>
<tr>
<td>• Average Initial Water Saturation</td>
<td>• Permeability</td>
</tr>
<tr>
<td>• Average Initial Oil Saturation</td>
<td>• Gross Thickness</td>
</tr>
<tr>
<td>• Average Initial Gas Saturation</td>
<td>• Dip Angle</td>
</tr>
<tr>
<td>• Average Formation Volume Factor</td>
<td>• Geologic Age Code</td>
</tr>
<tr>
<td><strong>Current Volumetrics</strong></td>
<td>• Geologic Play, Depositional System, Trap Type</td>
</tr>
<tr>
<td>• Current Oil Saturation (Swept Zone)</td>
<td></td>
</tr>
<tr>
<td>• Current Oil Formation Volume Factor</td>
<td></td>
</tr>
<tr>
<td><strong>Development and Performance Data</strong></td>
<td></td>
</tr>
<tr>
<td>• Recovery Efficiency</td>
<td>• Average Oil Gravity and Viscosity</td>
</tr>
<tr>
<td>• Well Spacing</td>
<td>• Initial GOR</td>
</tr>
<tr>
<td></td>
<td>• Current GOR</td>
</tr>
<tr>
<td></td>
<td>• Gas Impurities</td>
</tr>
</tbody>
</table>
Discovered Resources - Average Play Level Properties

- Assign each reservoir to USGS defined size class

- Calculate average properties for each size class
  - When no discovered field is in a size class, assign play level properties
Example: Assigning Average Porosity
--(Raw Data)--

Accumulation Distribution for Play 401:

<table>
<thead>
<tr>
<th>Play No.</th>
<th>Oil/ Gas</th>
<th>Number of Accumulations</th>
<th>Size Class Distribution from 1 to 15</th>
</tr>
</thead>
<tbody>
<tr>
<td>401</td>
<td>Oil</td>
<td>25</td>
<td>1 2 3 4 5 3 4 2 1 0 0 0 0 0 0</td>
</tr>
</tbody>
</table>

6 known reservoirs belong to play 401:

<table>
<thead>
<tr>
<th>Known Reservoir</th>
<th>Field Name</th>
<th>Recoverable (MMBL)</th>
<th>Porosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>AA</td>
<td>8.5</td>
<td>34%</td>
</tr>
<tr>
<td>B</td>
<td>CC</td>
<td>3.6</td>
<td>28%</td>
</tr>
<tr>
<td>C</td>
<td>AA</td>
<td>5.4</td>
<td>31%</td>
</tr>
<tr>
<td>D</td>
<td>BB</td>
<td>11.3</td>
<td>33%</td>
</tr>
<tr>
<td>E</td>
<td>CC</td>
<td>7.4</td>
<td>27%</td>
</tr>
<tr>
<td>F</td>
<td>AA</td>
<td>6.1</td>
<td>26%</td>
</tr>
</tbody>
</table>
Example: Assigning Average Porosity --(Calculations Contd…)--

Step 1: Group known reservoirs by field name, and determine size class

<table>
<thead>
<tr>
<th>Group No</th>
<th>Field Name</th>
<th>Reservoirs</th>
<th>Recoverable (MMBBL)</th>
<th>Total Recoverable (MMBBL)</th>
<th>Size Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>AA</td>
<td>A, C, F</td>
<td>8.5, 5.4, 6.1</td>
<td>20.0</td>
<td>5</td>
</tr>
<tr>
<td>2</td>
<td>BB</td>
<td>D</td>
<td>11.3</td>
<td>11.3</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>CC</td>
<td>B, E</td>
<td>3.6, 7.4</td>
<td>11.0</td>
<td>4</td>
</tr>
</tbody>
</table>
Example: Assigning Average Porosity
--(Calculations Contd...)--

Step 2: Calculate recoverable weighted average porosity for each group

Weighted Average Porosity = \( \frac{\text{Sum(Porosity} \times \text{Recoverable)}}{\text{Sum(Recoverable)}} \)

<table>
<thead>
<tr>
<th>Group No</th>
<th>Reservoir</th>
<th>Porosity</th>
<th>Recoverable (MMBBL)</th>
<th>Product</th>
<th>Weighted Average Porosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>A</td>
<td>34%</td>
<td>8.5</td>
<td>2.89</td>
<td></td>
</tr>
<tr>
<td></td>
<td>C</td>
<td>31%</td>
<td>5.4</td>
<td>1.674</td>
<td></td>
</tr>
<tr>
<td></td>
<td>F</td>
<td>26%</td>
<td>6.1</td>
<td>1.586</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>20.0</td>
<td>6.15</td>
<td>30.8%</td>
</tr>
<tr>
<td>2</td>
<td>D</td>
<td>33%</td>
<td>11.3</td>
<td>3.730</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>11.3</td>
<td>3.730</td>
<td>33.0%</td>
</tr>
<tr>
<td>3</td>
<td>B</td>
<td>28%</td>
<td>3.6</td>
<td>1.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>E</td>
<td>27%</td>
<td>7.4</td>
<td>1.998</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>11.0</td>
<td>3.008</td>
<td>27.4%</td>
</tr>
</tbody>
</table>
Example: Assigning Average Porosity
--(Calculations Contd…)--

Step 3: Calculate play average porosity

Play Average Porosity = \frac{\text{sum}(\text{Weighted Average Porosity for each Group} \times \text{Total Recoverable})}{\text{sum}(\text{Total Recoverable})}

<table>
<thead>
<tr>
<th>Group No</th>
<th>Weighted Average Porosity</th>
<th>Total Recoverable (MMBBL)</th>
<th>Product</th>
<th>Play Average Porosity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30.8%</td>
<td>20.0</td>
<td>6.16</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>33.0%</td>
<td>11.3</td>
<td>3.72</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>27.4%</td>
<td>11.0</td>
<td>3.0096</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>42.3</td>
<td>12.889</td>
<td>30.5%</td>
</tr>
</tbody>
</table>

Play 401 Average Porosity: 0.2990
Example: Assigning Average Porosity
--(Calculations Contd...)--

Step 4: Assign average porosity to size classes without known reservoir data

<table>
<thead>
<tr>
<th>Size class</th>
<th>Accumulation</th>
<th>Average Porosity</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>30.5%</td>
<td>Play Average</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>30.5%</td>
<td>Play Average</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>33.0%</td>
<td>Known Reservoir Average</td>
</tr>
<tr>
<td>4</td>
<td>4</td>
<td>27.5%</td>
<td>Known Reservoir Average</td>
</tr>
<tr>
<td>5</td>
<td>5</td>
<td>30.3%</td>
<td>Known Reservoir Average</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>30.5%</td>
<td>Play Average</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>30.5%</td>
<td>Play Average</td>
</tr>
<tr>
<td>8</td>
<td>2</td>
<td>30.5%</td>
<td>Play Average</td>
</tr>
<tr>
<td>9</td>
<td>1</td>
<td>30.5%</td>
<td>Play Average</td>
</tr>
</tbody>
</table>
Undiscovered Resources – Resource Estimates

- **Conventional**
  - Use 2005 Update for Resource Estimates
  - Determine Number of Accumulations in Each Size Class

- **Unconventional**
  - Use 2005 USGS Update for Resource Estimate
  - Assign Number of Cells to Each Play Based on Size Class
### What are the Size Classes?

**Conventional**

<table>
<thead>
<tr>
<th>Size Class Number</th>
<th>Gas Accumulation Size MMCF</th>
<th>Oil Accumulation Size MMBbl</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>&gt; 3</td>
<td>&gt; 0.5</td>
</tr>
<tr>
<td>1</td>
<td>&gt; 6</td>
<td>&gt; 1</td>
</tr>
<tr>
<td>2</td>
<td>&gt; 12</td>
<td>&gt; 2</td>
</tr>
<tr>
<td>3</td>
<td>&gt; 24</td>
<td>&gt; 4</td>
</tr>
<tr>
<td>4</td>
<td>&gt; 48</td>
<td>&gt; 8</td>
</tr>
<tr>
<td>5</td>
<td>&gt; 96</td>
<td>&gt; 16</td>
</tr>
<tr>
<td>6</td>
<td>&gt; 192</td>
<td>&gt; 32</td>
</tr>
<tr>
<td>7</td>
<td>&gt; 384</td>
<td>&gt; 64</td>
</tr>
<tr>
<td>8</td>
<td>&gt; 768</td>
<td>&gt; 128</td>
</tr>
<tr>
<td>9</td>
<td>&gt; 1,536</td>
<td>&gt; 256</td>
</tr>
<tr>
<td>10</td>
<td>&gt; 3,072</td>
<td>&gt; 512</td>
</tr>
<tr>
<td>11</td>
<td>&gt; 6,144</td>
<td>&gt; 1,024</td>
</tr>
<tr>
<td>12</td>
<td>&gt; 12,228</td>
<td>&gt; 2,048</td>
</tr>
<tr>
<td>13</td>
<td>&gt; 24,576</td>
<td>&gt; 4,096</td>
</tr>
<tr>
<td>14</td>
<td>&gt; 49,152</td>
<td>&gt; 8,192</td>
</tr>
<tr>
<td>15</td>
<td>&gt; 98,304</td>
<td>&gt; 16,384</td>
</tr>
</tbody>
</table>

**Unconventional**

<table>
<thead>
<tr>
<th>Size Class Number</th>
<th>Gas EUR Volume MMCF</th>
<th>Oil EUR Volume MMBbl</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&gt; 0</td>
<td>&gt; 0</td>
</tr>
<tr>
<td>2</td>
<td>&gt; 36</td>
<td>&gt; 6</td>
</tr>
<tr>
<td>3</td>
<td>&gt; 72</td>
<td>&gt; 12</td>
</tr>
<tr>
<td>4</td>
<td>&gt; 120</td>
<td>&gt; 20</td>
</tr>
<tr>
<td>5</td>
<td>&gt; 180</td>
<td>&gt; 30</td>
</tr>
<tr>
<td>6</td>
<td>&gt; 300</td>
<td>&gt; 50</td>
</tr>
<tr>
<td>7</td>
<td>&gt; 450</td>
<td>&gt; 75</td>
</tr>
<tr>
<td>8</td>
<td>&gt; 600</td>
<td>&gt; 100</td>
</tr>
<tr>
<td>9</td>
<td>&gt; 1,200</td>
<td>&gt; 200</td>
</tr>
<tr>
<td>10</td>
<td>&gt; 1,800</td>
<td>&gt; 300</td>
</tr>
</tbody>
</table>

Defined by USGS
Number of Accumulations by Size Class

Size Class

Expected # of Accumulations

Discovered

Undiscovered
Undiscovered Resource – Assign Properties

- For Each Accumulation / Cell

- Assign Play Level Properties Based on
  - Size Class
  - Play Average

Master Database

- Discovered
  - Calculate Average Well Production Profile For Field
  - Assign Field Level Properties to Each Well
  - Calculate Average Properties for a Play
  - Aggregate Production at Play Level
  - Define Bins
  - Generate Resource Files

- Undiscovered
  - Define Resource Estimates Using USGS
  - Assign Play Level Properties to Each Accumulation/Cell
Binning of Resource Data

- Due to the Proprietary Nature of the Resource Data, the Discovered Resource Will be Classified in Pseudo-Bins Based on its Production Volumes and Depth
- Each Well is Assigned a Size and Depth Bin Category

<table>
<thead>
<tr>
<th>Size Range (BOE/Day)</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td></td>
</tr>
<tr>
<td>&gt;10-15</td>
<td></td>
</tr>
<tr>
<td>&gt;15-50</td>
<td></td>
</tr>
<tr>
<td>&gt;50-100</td>
<td></td>
</tr>
<tr>
<td>&gt;100</td>
<td></td>
</tr>
</tbody>
</table>

Depth of Producing Zone (Feet)

<table>
<thead>
<tr>
<th>Depth Range</th>
<th>Number of Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2000</td>
<td></td>
</tr>
<tr>
<td>&gt;2000-4000</td>
<td></td>
</tr>
<tr>
<td>&gt;4000-8000</td>
<td></td>
</tr>
<tr>
<td>&gt;8000-12000</td>
<td></td>
</tr>
<tr>
<td>&gt;12000-15000</td>
<td></td>
</tr>
<tr>
<td>&gt;15000</td>
<td></td>
</tr>
</tbody>
</table>

for each size bin
Example of Binning Wells

- Assume 15 Wells in a Hypothetical Play
- The Size Category and Depth Category Are Determined for Each Well

<table>
<thead>
<tr>
<th>Well Number</th>
<th>Average Production (BOE)</th>
<th>Average Depth (FT)</th>
<th>Size Category</th>
<th>Depth Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>9</td>
<td>4500</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>8</td>
<td>4350</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>3</td>
<td>15</td>
<td>3700</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>25</td>
<td>4500</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>5</td>
<td>25</td>
<td>2900</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>30</td>
<td>5100</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>45</td>
<td>4625</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>8</td>
<td>7</td>
<td>3975</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>12</td>
<td>4150</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>18</td>
<td>4300</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>11</td>
<td>13</td>
<td>4450</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>12</td>
<td>5</td>
<td>4750</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>13</td>
<td>9</td>
<td>4950</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>14</td>
<td>38</td>
<td>4600</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>15</td>
<td>40</td>
<td>5150</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>
Example of Binning Wells (Cont)

- The Bin Population Is the Total Number of Wells in Each Size and Depth Category Combination
- The Empty Bins Are Not Shown

<table>
<thead>
<tr>
<th>Size Category</th>
<th>Depth Category</th>
<th>Bin Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
</tbody>
</table>
Example of Well Binning (Cont)

- Decline Curve Analysis is Used to Determine the Size Category of Each Well in Subsequent Years (for Future Technology Advancements)

- This Well is in:
  - Bin 3  Year 1 – 4
  - Bin 2  Year 5 – 14
  - Bin 1  Year 15 - 25
Summary

• Resource Description Module will Process and Create the Data Required for the Following Resources

  ➢ Oil
    • Conventional
    • Unconventional

  ➢ Gas
    • Conventional
    • Unconventional
Onshore Lower 48 Oil & Gas Supply Submodule

Process Module & Technical Screening
Discussion Items

- Goal
- Process Model
- Production Profile Function Approach
- Technology Screening Criteria
Goal & Objective

- To Forecast Future Production Potential from Oil & Gas Fields Based on their
  - Geologic Properties
  - Petrophysical Properties
Three Phases of Future Production

• Existing Production
  ➢ From Currently Producing Oil & Gas Fields

• Reserves Growth
  ➢ ASR / EOR
  ➢ Infill Drilling

• Undiscovered Resource
Existing Production

- Use Production Profile Function Approach for Both
  - Oil
  - Gas

- QA/QC Process
  - Perform Back Casting Analysis to Validate Decline Curve
Reserves Growth

• Production Profile Functions for Estimating Reserves Growth

  ➢ Oil
    • Advanced Secondary Recovery
    • Enhanced Oil Recovery
    • Infill Drilling

  ➢ Gas
    • Infill Drilling
## Processes Modeled

<table>
<thead>
<tr>
<th>Oil</th>
<th>Gas</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Water Flooding</td>
<td>- Conventional</td>
</tr>
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<td>- Water Drive</td>
</tr>
<tr>
<td>- CO2 Flooding</td>
<td>- Tight Sands</td>
</tr>
<tr>
<td>- Steam Flooding</td>
<td>- Coal / Shale</td>
</tr>
<tr>
<td>- Infill Drilling</td>
<td></td>
</tr>
<tr>
<td>- Profile Modification</td>
<td></td>
</tr>
<tr>
<td>- Horizontal Wells</td>
<td></td>
</tr>
</tbody>
</table>
Production Profile Development Procedure

- Identify predictive model for a specific process
- Identify variables critical to the process (4-5 / process)
- Run predictive model by changing one variable at a time
  - Number of runs = “n” variables X “m” changes
- Generate a production profile equation as a function of n variables

\[ \text{Prod}_{iyr} = f(var_1, var_2, \ldots, var_n)_{iyr} \]
Example: Generic Production Profile Curves for CO$_2$ Flooding

- Critical Variables
  - Depth
  - Minimum Miscibility Pressure (mmp)
  - WAG
  - CO$_2$ Pore Volume Injected
  - Permeability ($k$)
  - Porosity ($\Phi$)

Production Profile = $f(Depth, mmp, k, \Phi)$
Technology Screening

• Every Size Class Oil Bin will be Assigned to One Or More Possible Processes for ASR/EOR

• For Gas Bins, Technology Screening will be Applied Based on Lithology, Drive Mechanism, and Geologic Properties
# Existing Screening Criteria for EOR Processes

<table>
<thead>
<tr>
<th>Rock Type</th>
<th>Alkaline</th>
<th>MCP</th>
<th>CO2 Miscible Flooding</th>
<th>Imp. Steam Flooding</th>
<th>Adv. Steam Flooding</th>
<th>In-situ Combustion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Oil Gravity, API</td>
<td>&lt; 30</td>
<td>≥ 25</td>
<td></td>
<td>10 to 34</td>
<td>10 to 35</td>
<td></td>
</tr>
<tr>
<td>In-situ Oil Viscosity, cp</td>
<td>&lt; 90</td>
<td>&lt; 40</td>
<td></td>
<td>≤ 15,000</td>
<td></td>
<td>≤ 5,000</td>
</tr>
<tr>
<td>Depth, ft</td>
<td></td>
<td>≤ 3,000</td>
<td></td>
<td>≤ 5,000</td>
<td>≤ 11,500</td>
<td></td>
</tr>
<tr>
<td>Net Pay, ft</td>
<td></td>
<td>≥ 20</td>
<td></td>
<td>≥ 15</td>
<td>≥ 20</td>
<td></td>
</tr>
<tr>
<td>Reservoir Temp. (°F)</td>
<td>&lt; 200</td>
<td>&lt; 200</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Porosity, Φ</td>
<td></td>
<td>≥ 20*</td>
<td></td>
<td>≥ 15*</td>
<td>≥ 20*</td>
<td></td>
</tr>
<tr>
<td>Avg. Perm., md</td>
<td>&gt; 20</td>
<td>&gt; 40</td>
<td></td>
<td>≥ 250</td>
<td>≥ 10</td>
<td>≥ 35</td>
</tr>
<tr>
<td>Transmissibility, md-ft/cp</td>
<td></td>
<td>≥ 5</td>
<td></td>
<td>≥ 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Reservoir Pressure, psi</td>
<td></td>
<td>≥ MMP</td>
<td>≤ 1,500</td>
<td>≤ 2,000</td>
<td>≤ 2,000</td>
<td></td>
</tr>
<tr>
<td>Minimum Oil Content at Start (So*Φ)</td>
<td></td>
<td>≥ 0.10</td>
<td>≥ 0.08</td>
<td>≥ 0.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salinity of Formation Brine, ppm</td>
<td>&lt; 100,000</td>
<td>&lt; 100,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rock Type</td>
<td>Sandstone</td>
<td>Sandstone</td>
<td>Sandstone or Carbonate</td>
<td>Sandstone or Carbonate</td>
<td>Sandstone or Carbonate</td>
<td>Sandstone or Carbonate</td>
</tr>
</tbody>
</table>

*Ignore if Soi*Por. is satisfied
# Gas Technology Screening

<table>
<thead>
<tr>
<th>Lithology</th>
<th>Permeability</th>
<th>Depth</th>
<th>Drive</th>
<th>Other TBD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conventional</td>
<td>Sandstone Carbonates</td>
<td></td>
<td>All Depths</td>
<td></td>
</tr>
<tr>
<td>Tight Sands</td>
<td>Sandstone Carbonates</td>
<td>&lt;= 0.1</td>
<td>All Depths</td>
<td></td>
</tr>
<tr>
<td>Coal/Shale</td>
<td>Coal/Shale</td>
<td></td>
<td>All Depths</td>
<td></td>
</tr>
<tr>
<td>Water Drive</td>
<td>Sandstone Carbonates</td>
<td></td>
<td>All Depths</td>
<td>Water Drive</td>
</tr>
</tbody>
</table>
Onshore Lower 48 Oil & Gas Supply Submodule

Modeling & Technology Options
Discussion Items

• Phases of Technology Development
• Uncertainty
• How We Account for Uncertainty
• The Technology Penetration Curve
### Three Phases of Technology Development

<table>
<thead>
<tr>
<th>Time</th>
<th>Fraction of Industry Using Technology</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>R&amp;D Phase</td>
</tr>
<tr>
<td></td>
<td>Market Acceptance</td>
</tr>
<tr>
<td></td>
<td>Market Saturation</td>
</tr>
</tbody>
</table>

- **R&D Phase**: Research and Development
- **Market Acceptance**: The technology is adopted by the industry.
- **Market Saturation**: The technology is widely adopted and used by the industry.

**Graphical Representation**

- The graph shows the progression of technology development over time, with the fraction of industry using the technology increasing from 0 to 1.
- It highlights the phases of R&D, demonstration, and market acceptance.

**Key Events**

- **Demonstration**: The technology is first demonstrated to the industry.
- **Market Acceptance**: The technology is accepted by the market.
- **Market Saturation**: The technology is fully integrated into the market.
Three Phases of Technology Development

- **RD&D Phase (Outcome)**
  - Technology May be a Success
  - Technology May be Unsuccessful
  - Performance May Be a Fraction of Targeted Goals
  - Chances of Success

- **Implementation Phase**
  - Effective or Not Effective
  - Lack of Understanding
  - Lack of Access to Technology
  - Market Acceptance
# Summary of Uncertainties

<table>
<thead>
<tr>
<th></th>
<th>Technology</th>
<th>Economic</th>
<th>Market</th>
</tr>
</thead>
<tbody>
<tr>
<td>Existing Technology</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>Advanced Technology</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>New Technology</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
</tbody>
</table>

To be discussed later
# Modeling Uncertainty & Risk

- Identify Critical Parameters Affecting Each Technology
- Generate Technology/Market Penetration Curve

## Impx

\[ \text{Imp}_x = f(Y_d, Y_c, Y_a, UP, Ps, Pi) \]

<table>
<thead>
<tr>
<th>Name</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yd</td>
<td>Number of years required to develop technology</td>
</tr>
<tr>
<td>Yc</td>
<td>First year of commercialization</td>
</tr>
<tr>
<td>Ya</td>
<td>Number of years to fully penetrate the market</td>
</tr>
<tr>
<td>UP</td>
<td>Ultimate market penetration (%)</td>
</tr>
<tr>
<td>Ps</td>
<td>Probability of success</td>
</tr>
<tr>
<td>Pi</td>
<td>Probability of Implementation</td>
</tr>
<tr>
<td>Impx</td>
<td>Percent of industry implementing the technology in a given year x</td>
</tr>
</tbody>
</table>

![Market Penetration vs Years Graph](image-url)

---

**INTEK**
Effect of Market Penetration Curve on Technologies

Three Major Effects:

- Effect on Overall Production Profile of the Resource
- Effect on Economics of the Resource
- Combination of Both
Effects of Technology Development

A: Base Case

B: Improvement of Production

C: Improvement of Project Economics
Impacts of Multiple Technologies

Measuring Technology Impacts

Mutually Exclusive (M): Or

Additive (A): +=

Synergetic (S):

Rules will be Developed to Identify Interactions
Example

- Reservoir Characteristics Help Improve Production by 15%
- Drilling Bit Improvements Help Reduce Drilling Cost by 10%

These Technologies are Mutually Exclusive, Additive, or Synergetic
Implementation of Technology Options

1. Identify Levers
2. Develop Market Penetration Curves
3. Determine Technology Interactions
4. Develop Technology Implementation Profiles

- Review with Industry Experts
- DOE R&D Program
- Others
Onshore Lower 48 Oil & Gas Supply Submodule

Economic/Timing Module
Discussion Items

• Role of Timing/Economic Module

• Overall Logic
  ➢ System / Timing Module

• Components of Timing Module
  ➢ Input Data
  ➢ Exploration – Conventional & Unconventional
  ➢ Discovered Resource
  ➢ Selection & Ranking
  ➢ Resource Development Constraints

• Model Applications

• Reports
Role of Timing/Economic Module

• Projects Future Oil & Gas Supply at Play Level
  - 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
    • CO₂ Availability
    • Pipeline
    • Others
### Processes Modeled

<table>
<thead>
<tr>
<th>Oil</th>
<th>Gas</th>
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<tr>
<td>- Water Flooding</td>
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<tr>
<td>- CO2 Flooding</td>
<td>- Tight Sands</td>
</tr>
<tr>
<td>- Steam Flooding</td>
<td>- Coal / Shale</td>
</tr>
<tr>
<td>- Infill Drilling</td>
<td></td>
</tr>
<tr>
<td>- Profile Modification</td>
<td></td>
</tr>
<tr>
<td>- Horizontal Wells</td>
<td></td>
</tr>
</tbody>
</table>
Overall System Logic Flow

Master Database

Resource Description Module

Process Module

Economic/Timing Module

Performs Economic Evaluation of Oil and Gas Resources
– Discovered and Undiscovered
– Rank and Select Resources for Development
– Provides Supply Curves for NEMS

Model Option Files
Components of Timing Module

Input Data

Exploration

Secondary/Tertiary Recovery

Projection of Existing Production

Selection/Ranking

Aggregation

Reports
A- Input Data

- **Resource Data**
  - Discovered
  - Undiscovered
- **Process Production Profile Parameters**
- **Cost Data**
- **Constraints**
- **Economic Parameters (Price, ROR, etc…)**
- **Fiscal Data**
- **User Defined**
  - Technology Levers
  - Economic Levers
  - Control Variables
Types of Cost Data

- Economic Module
  - Capital Costs
    - Resource/Process Independent
  - Operating Costs
    - Resource/Process Specific
    - Fixed Operating & Maintenance
  - Other Cost Parameters
    - Variable Operating & Maintenance
Capital Cost Data

• Resource/process independent:
  - Drilling & completion
  - Workover
  - Surface and Subsurface facilities

\[ f(\text{depth}) \text{ region} \]

• Resource/process dependent:
  - Gas processing facilities
  - CO₂ injection plants
  - Steam generators
  - Environmental costs

\[ f(\text{CO}_2 \text{ injection volume}) \]
\[ f(\text{steam injection volume}) \]
Operating Cost Data

- **Fixed operating costs:**
  - Direct annual operating costs \( f(\text{depth}) \) _region_
  - Secondary production costs

- **Variable operating costs:**
  - Lifting cost \( ($/\text{Bbl}, $/\text{Mcf}) \)
  - Gas processing cost \( ($/\text{Bbl}, $/\text{Mcf}) \)
  - CO\(_2\) cost \( ($/\text{Mcf}) \)
  - Chemical \( ($/\text{Bbl}) \)
  - Recycling \( ($/\text{Bbl}, $/\text{Mcf}) \)
  - Environmental costs \( ($/\text{Bbl}, $/\text{Mcf}) \)
  - G&A on Capital and Operating Costs factors
Developing Cost Equations

• Determine historical cost data
• Determine corresponding oil price
• Normalize all costs data to a fixed oil price ( $30/bbl)
• Develop regional cost equations as a function of critical parameters:
  ➢ Depth
  ➢ Production Rate
  ➢ Injection Rate
  ➢ Others (TBD)

• Test cost equation for validity
Cost Adjustment Factors

- Capital and operating costs vary with supply & demand and also oil price
- Cost adjustment multipliers will be used to capture the impact of oil price changes
- Use National Petroleum Council (NPC) methodology for price impacts
NPC Methodology For Price Impacts

• Determine the ratio of the change between the current oil price and the fixed price

\[
\text{Term} = \frac{(\text{Oil Price}_{\text{current}} - \text{Fixed Price})}{\text{Fixed Price}}
\]

• Apply adjustment multipliers for various cost categories:

\[
(Cost\ Multiplier)_x = 1 + (Factor)_x \times (Term)
\]

<table>
<thead>
<tr>
<th>Cost Category</th>
<th>Factor $x$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tangible Investments</td>
<td>0.2</td>
</tr>
<tr>
<td>Intangible Investments</td>
<td>0.4</td>
</tr>
<tr>
<td>Operating Costs - Fixed</td>
<td>0.2</td>
</tr>
<tr>
<td>CO$_2$</td>
<td>0.39</td>
</tr>
<tr>
<td>Polymer</td>
<td>0.3913</td>
</tr>
<tr>
<td>Other Costs</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Source: COGAM

To be validated against current data
Resource Development Constraint Files

- **Drilling Constraints**
  - Total number of rigs
  - Rig depth rating
  - Total development & exploration drilling (footage)

- **CO₂ Availability**
  - Sources of CO₂: Type, State, Region
  - Volume of CO₂ available by source

- **Capital Constraints**
  - Total capital available for E&P activity
  - Resource Access

Function of oil & gas prices
Other Economic Parameters

- Other economic parameters includes:
  - Depreciation schedule
  - Depletion rate
  - Amortization schedule
  - Environmental costs
  - Lease acquisition costs
  - Geological & geophysical costs

- Oil & Gas prices:
  - Annual oil & gas prices
  - Fixed or variable
Model Levers

• Technology levers
  ➢ Value of all levers
  ➢ Implementation & market penetration curves
  ➢ Interaction of Technologies

• Economic Levers
  ➢ ROR
  ➢ Risk

• User defined run controls
  ➢ Types of Output
  ➢ Single or Multiple Cases
  ➢ Other

Resource access parameters
Economic Risk

- Economic Risk is Modeled Using Rate of Return

- Two Components of Rate of Return
  - Cost of Capital – 6% to 8% (historical average)
  - Technology Risk – Varies with Technology
Components of Timing Module

Input Data

Exploration

Secondary/Tertiary Recovery

Projection of Existing Production

Selection/Ranking

Aggregation

Reports
Detailed Timing/Economic Module Flowchart

1. Input Data
2. For Each Year
3. Populate Bins
4. Exploration
5. Exploration Economics
6. Production Decline
7. Economics
8. Create Pseudo-Projects
9. Define Reserve Growth
10. Pseudo-Economics
1: Step Where Technology Levers Will Be Used
2: Step Where Economic Levers Will Be Used
3: Step Where Resource Access Levers Will Be Used

Detailed Timing/Economic Module Flowchart (Contd…)

1. Project Ranking ²
2. Timing/Selection ²,³
3. Aggregation
4. Is It the Last Year?
   - No
   - Yes
5. Reports
6. Input to Other Modules
7. Output Files
B: Populate Bins

- Read Resource Files
- Populate Bins for Each Play Based on Size Class & Depth

Read Data

For Each Year

Populate Bins

Exploration1

Exploration Economics2

Production Decline

Economics

Create Pseudo-Projects1

Define Reserve Growth

Pseudo-Economics2

Project Ranking2

Timing/Selection2,3

Aggregation

Is it the Last Year?

Yes

No

Reports

Input to Other Modules

Output Files

---

Size (BOE/Day)

<table>
<thead>
<tr>
<th>Size Range</th>
<th>Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-10</td>
<td></td>
</tr>
<tr>
<td>&gt;10-15</td>
<td></td>
</tr>
<tr>
<td>&gt;15-50</td>
<td></td>
</tr>
<tr>
<td>&gt;50-100</td>
<td></td>
</tr>
<tr>
<td>&gt;100</td>
<td></td>
</tr>
</tbody>
</table>

Depth of Producing Zone (Feet)

<table>
<thead>
<tr>
<th>Depth Range</th>
<th>Number of Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2000</td>
<td></td>
</tr>
<tr>
<td>&gt;2000-4000</td>
<td></td>
</tr>
<tr>
<td>&gt;4000-8000</td>
<td></td>
</tr>
<tr>
<td>&gt;8000-12000</td>
<td></td>
</tr>
<tr>
<td>&gt;12000-15000</td>
<td></td>
</tr>
<tr>
<td>&gt;15000</td>
<td></td>
</tr>
</tbody>
</table>
An Example of Bin Populations

The population of bins in YEAR I at the beginning of the YEAR loop for a play:

<table>
<thead>
<tr>
<th>Size Bin</th>
<th>Depth Bin</th>
<th>Number of Wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>3</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3</td>
<td>2</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

Note: Only bins with data are shown in this example.
C: Exploration in Timing Module

- Exploration
  - Conventional
  - Unconventional
    - Volume Based Method
    - Pseudo-Monte Carlo
      - Discovery Order List

- Exploration Economics
  - Read Data
  - For Each Year
  - Populate Bins
  - Production Decline
  - Economics
  - Create Pseudo-Projects
  - Define Reserve Growth
  - Pseudo-Economics
  - Project Ranking
  - Timing/Selection
  - Aggregation

- Is It the Last Year?
  - Yes
    - Reports
    - Input to Other Modules
  - No

- Output Files
Exploration Sub Module

• Objective: to Evaluate Economic Potential For Undiscovered Oil & Gas Resources
  ➢ Conventional
  ➢ Unconventional

• Based on Undiscovered Resource Estimates
Ultimate Goal of the Exploration Model

- To Determine the Discovery Order of Accumulation/Cell within a Region/Play

<table>
<thead>
<tr>
<th>Discovery Order</th>
<th>Play No.</th>
<th>Accumulation/Cell ID</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
</tr>
<tr>
<td>n</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Exploration
-Conventional Resource-
Exploration: Conventional Resource

• Proposed Method to Calculate Probability
  ➢ Volume based

• Exploration effectiveness is modeled using:
  ➢ Technology factors
  ➢ Favorability factors (such as resource access)

Methodology Accommodates Theories & Methods Developed by Industry/Government
Modeling Conventional Exploration

• Rules for Exploration:
  - First explore the plays with the largest remaining reserves
  - Use the volume to calculate the probability of discovery of each class in the play
  - Aggregate and normalize the class discovery probabilities to determine the discovery probability of the play
  - Make selections using the cumulative probabilities and a pseudo-random number
Modeling Conventional Exploration (Cont.)

- Adjust probabilities using:
  - Technology levers
  - Resource access levers
- Add to list for competition with other resources
Adjusting Probabilities for Conventional Exploration

- **Technology Factor:**
  - Drilling
  - Resource description

- **Resource Access Factor:**
  - Resource is available
  - Resource is unavailable

### Example

<table>
<thead>
<tr>
<th>Play</th>
<th>Technology Factor</th>
<th>Resource Access</th>
</tr>
</thead>
<tbody>
<tr>
<td>401</td>
<td>0.95</td>
<td>1.00</td>
</tr>
<tr>
<td>403</td>
<td>1.05</td>
<td>1.00</td>
</tr>
<tr>
<td>450</td>
<td>1.00</td>
<td>1.15</td>
</tr>
<tr>
<td>451</td>
<td>1.00</td>
<td>0.85</td>
</tr>
<tr>
<td>503</td>
<td>0.85</td>
<td>0.95</td>
</tr>
<tr>
<td>1001</td>
<td>1.10</td>
<td>1.00</td>
</tr>
<tr>
<td>1007</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>1102</td>
<td>0.90</td>
<td>1.10</td>
</tr>
<tr>
<td>1301</td>
<td>0.85</td>
<td>0.95</td>
</tr>
<tr>
<td>1804</td>
<td>1.00</td>
<td><strong>0.10</strong></td>
</tr>
<tr>
<td>2005</td>
<td>1.10</td>
<td>1.00</td>
</tr>
<tr>
<td>2057</td>
<td>0.85</td>
<td>0.85</td>
</tr>
<tr>
<td>2206</td>
<td>1.00</td>
<td><strong>1.05</strong></td>
</tr>
<tr>
<td>2503</td>
<td>1.00</td>
<td><strong>1.20</strong></td>
</tr>
<tr>
<td>2801</td>
<td>0.90</td>
<td>1.00</td>
</tr>
</tbody>
</table>

- **Resource is unavailable**
- **No Resource Access Constraints**
**Exploration Technology Factor**

How Do We Model the Effects of Exploration Technologies?

Technology Enhances the Probability of Exploratory Success for Applicable Resources

Source: COGAM
Exploration
-Unconventional Resource-
Exploration: Unconventional Resource

- Modeled using a two step process

- Step 1: Determine probable exploration/development schedule for all cells in each play
  - Use pseudo Monte Carlo methodology
  - Run every year

- Step 2: Determine the development order for all plays while incorporating:
  - Technology
  - Resource access
Important Definitions

• Unit of Analysis: **Play**

• Exploration Unit: **Cell** (as defined by USGS)

• Annual Drilling Package:
  - In a play
  - Randomly selected set of cells
Modeling Unconventional Exploration

- Calculate probability of discovery of each cell bin as a function of EUR
- Create drilling packages using pseudo random methodology
- Select first package
- Run economics
  - If economic: Select next package
  - If not economics: Add next package for next year and run economics
- Repeat process for next package
- Determine discovery order using probabilities
- Add to list for competition with other resources
Exploration: Discovered Order

- Conventional List
- Unconventional List
- Exploration Economics
- Selection & Ranking
Exploration Economics

• All Exploration Costs are Assumed to be Sunk Costs

• Full Development Economics is Performed on Each Accumulation/Cell
  ➢ Development Drilling Costs
  ➢ Lease Acquisition Cost
  ➢ Capital Equipment Cost for New Producers
  ➢ Fixed and Variable Operating Costs
  ➢ Only Primary Production is Considered for Economic Calculation
Exploration
-Discovered Resource-
D: Production Decline Submodule

- For each play & bin:
  - Assign & calculate average historical production profile
  - Perform decline curve analysis at bin level using bin size/depth as one of the production profile parameters
  - Perform economics of the future profile
D: Production Decline Submodule (Cont.)

- If economic:
  - Scale economics and production from one well to the number of wells in the bin
  - Aggregate the production from that bin
  - Tag the bin as economic (section G)

- If uneconomic:
  - Tag the uneconomic bin for reserves growth (section E)

- Repeat for each bin and each play
E: Reserve Growth Submodule

- Aggregate the wells in uneconomic bins

- Determine which bins can not be combined in pseudo-projects due to:
  - Depth
  - Average play properties

- Create pseudo-projects by selecting wells using pseudo-random methodology
E: Reserve Growth Submodule (Cont.)

- For each pseudo-project:
  - Determine, using screening criteria applied to the play average properties, which reserve growth processes are applicable
  - Using process specific type curves, and model levers, determine the potential additional production from EACH reserve growth process
  - Apply technology levers as applicable
  - Calculate life cycle economics on pseudo projects using process specific costs & schedule
  - Calculate investment efficiency
  - Store the project for ranking

- Repeat this process for all pseudo projects
**F: Project Ranking Submodule**

- **Read the list of projects**
  - Reserve growth projects from step E
  - Exploration projects from step C
- **Read YEAR**
- **For Every Region:**
- **Rank projects by:**
  - Investment efficiency (reserves growth)
  - Probability of discovery (exploration)
- **If YEAR >1:**
  - Add the “Economic Undeveloped” projects from YEAR – 1 to the top of the list
- **Transfer list of potential projects to Timing/Selection (step G)**
G: Timing & Aggregation Submodule

- Read list of ranked projects
- Read constraint data and model levers
- For every region:
  - Check project at top of the list
  - Determine if sufficient constraints are available
  - Determine project’s resource access category
  - Check that development of project would not exceed play level estimates
G: Timing & Aggregation Submodule (Cont.)

- Check if project has passed the “shut in” window
- If project has passed “shut in”:
  - Calculate shut-in costs
  - Calculate environmental costs
  - Tag as “Shut in”
  - Examine next project
- If project has not passed “shut in” window:
G: Timing & Aggregation Submodule (Cont.)

- If constraints are available:
  - Time in project
  - Tag as “Economic Developed”
  - Remove from list
  - Remove duplicate projects
  - Calculate remaining constraints
  - Check next project

- If constraints are not available:
  - Read remaining projects for that region
  - Tag the economic projects as “Economic Undeveloped”
  - Tag the project, for potential shut in, in YEAR + 1
  - Delete uneconomic projects
G: Timing & Aggregation Submodule (Cont.)

- End the reading and evaluation of projects
- Repeat for all projects/regions and run aggregation
Economics

- Each Project will be Subject to Detailed Full Cycle Cashflow Analysis
Onshore Lower 48 Oil & Gas Supply Submodule

Resource Development Constraints
Resource Development Constraint Data

New OLOGSS

1. Resource Data
   - Map of Oil and Natural Gas Reservoirs in the United States

2. Production Data
   - Line graph showing production over time

3. Cost Data
   - Image of cost documents and a dollar symbol

4. Development Constraint Data
   - Image of drilling and construction equipment
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
  - Access to Land – Federal/State
  - Others to be Defined
# Sources of Resource Development Constraints

<table>
<thead>
<tr>
<th>Resource Development Constraint</th>
<th>Data Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drilling Constraints</td>
<td></td>
</tr>
<tr>
<td>Number of Rigs</td>
<td>API, Baker Hughes, Smith Bits</td>
</tr>
<tr>
<td>Rig Depth Rating</td>
<td>API, Baker Hughes, Smith Bits</td>
</tr>
<tr>
<td>Development Drilling</td>
<td>EIA, API, IPAA, OGJ</td>
</tr>
<tr>
<td>Exploratory Drilling</td>
<td>EIA, API, IPAA, OGJ</td>
</tr>
<tr>
<td>Capital Expenditures</td>
<td>EIA, API</td>
</tr>
<tr>
<td>Other Constraints</td>
<td></td>
</tr>
<tr>
<td>CO₂ Availability/Pipeline capacity</td>
<td>OGJ, Kinder Morgan, NATCARB</td>
</tr>
</tbody>
</table>
US Historical Drilling Activity

- Year: 1990 to 2005
- # of Wells Drilled
- Source: 2005 Annual Energy Review (EIA)
Wells Drilled Annually is Function of Oil Price

Source: 2005 Annual Energy Review (EIA)
So is Footage Drilled

Source: 2005 Annual Energy Review (EIA)
Relationship between Oil Price and Drilling

Without Lag

Source: 2005 Annual Energy Review (EIA)
Capital Expenditures - Onshore

- Major U.S. Companies’ Expenditures for Onshore Crude Oil and Natural Gas Exploration and Development

Source: 2005 Annual Energy Review (EIA), with prices adjusted to 2004 Dollars
Relationship between Oil Price and Capital Expenditures

Without Lag

With 1 year Lag

Source: 2005 Annual Energy Review (EIA)
Major U.S. Companies Expenditures for Onshore Oil and Natural Gas Exploration & Development
Expenditures adjusted to 2004 Dollars
CO₂ Constraints

- Natural Sources
- Industrial Sources
  - Existing – Connected to Infrastructure
  - Existing – Not Connected to Infrastructure
  - New Sources – CTL, Power Plants, Oil Shale Retort, etc …
Natural CO₂ Sources – Existing Infrastructure

Current CO₂ Sources, Pipelines

Total = 945 Bcf/Yr

Source: Oil & Gas Journal
Industrial CO₂ Sources – Fossil Fuel Plants

Total = 3,057 Bcf/Yr

Source: INTEK
Resource Access

- Play Specific
  - % of Resource on Federal Lands Accessible for Development
  - % of Resource on Federal Lands Not Accessible for Development

- Other Limiting Factors to be Determined
Onshore Lower 48 Oil & Gas Supply Submodule

Model Applications
Model Applications

• Future Production Profile
  ➢ Business As Usual (BAU) Case
  ➢ Advanced Technology Scenario

• Different Resource Access Scenarios

• Development of New Resources
Model Applications

• Effect on Onshore Lower 48 Oil & Gas Production as a result of:
  - New Tax Incentives
  - Environmental Regulation
  - Proposed Legislation Changes
  - Proposed Tax Law Changes
  - Other Policy Analyses
Overall System Logic Flow

- Master Database
- Resource Description Module
- Process Module
- Economic/Timing Module
- Reports

Other Input
- Costs
- Fiscal Data

Model Option Files

Additional Information:
- Production and Reserves
- Wells – Active and Drilled
- Economic results
- Aggregated at:
  - Play
  - Basin
  - State/Regional
  - National
Reports Module: Role in OLOGSS

- The Reports Module transfers the results from the OLOGSS to:
  - Other OGSM modules
  - NEMS
  - User

- Allows iteration of supply and demand
Reports Module: Summary of Outputs

• Production Price Supply Curves
  ➢ Oil
  ➢ Natural Gas
    • Non-associated
    • Associated-dissolved
  ➢ Reported by
    • Resource Access Category
    • Play
    • State
    • Region
    • National
Reports Module: Summary of Outputs (Contd…)

• Drilling statistics disaggregated by
  ➢ Exploratory
  ➢ Developmental
  ➢ For oil and gas
  ➢ Reported by
    • Play
    • State
    • Region
    • National
Reports Module: Summary of Outputs (Contd…)

• Economic Reports

• Resource Development Constraints Utilized

• Detailed reports for analysis of
  ➢ Technology
  ➢ Changes in taxes
  ➢ Access issues

• Other reports to be determined
OPEN DISCUSSION