Oxy CO$_2$ EOR Project
Occidental of Elk Hills, Inc.
May 21, 2010
Outline

- Oxy CO$_2$ Business
- HECA Project Description
- Oxy CO$_2$ EOR Project Description
- Site Suitability for Sequestration
**CO₂ EOR in the United States**

- **Rockies**
  - 20 Projects
  - 39,500 Gross Bbls/d
  - Operators: Exxon/Anadarko/Merit
  - CO₂ Source: Natural/Manufacturing

- **Mid-Continent**
  - 8 Projects
  - 13,000 Gross Bbls/d
  - Operators: Merit/Chaparral/Whiting
  - CO₂ Source: Manufacturing

- **Permian Basin**
  - 69 Projects
  - 187,000 Gross Bbls/d
  - Operators: Various
  - CO₂ Source: Natural

- **Eastern Gulf Coast**
  - 17 Projects
  - 42,000 Gross Bbls/d
  - Operators: Denbury
  - CO₂ Source: Natural
CO₂ Floods in the Permian Basin

Number of Active Operated CO₂ Projects

- First floods initiated 35 years ago
- Over 60 CO₂ floods in Permian Basin

16 other companies

Oxy transports and injects more CO₂ than any other company in the world
CO₂ EOR is Growing

CO₂ EOR is a proven technology and is growing

Note: Based on data obtained from the 2010 O&G Journal bi-annual EOR Survey
**Oxy Operated CO₂ Projects**

*(Date Started)*

- North Cross (1972)
- GMK South (1982)
- Denver Unit (1983)
- Central Mallet (1984)
- Frazer Unit (1984)
- Slaughter Estate (1984)
- Wasson ODC (1984)
- South Wasson Clfk (1985)
- Willard Unit (1986)
- South Cross (1988)
- Salt Creek Unit (1993)
- South Welch Unit (1993)
- Cedar Lake Unit (1994)
- Elmar Delaware Unit (1994)
- Bennett Ranch Unit (1995)
- North Cowden Unit (1995)
- Anton Irish Clfk Unit (1997)
- Mid Cross (1997)
- North Dollarhide Dvn (1997)
- West Welch Pilot (1997)
- Sharon Ridge Unit (1999)
- TSTAR Abo (1999)
- Cogdell Unit (2001)
- HT Boyd (2001)
- North Hobbs Unit (2003)
- Levelland Unit (2004)
- Igoe Smith Unit (2005)
- West RKM (2006)
- North West Mallet (2007)
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HECA Site Location

HECA site close to:
- CO₂ injection point and geologic storage formation
- Adequate non-potable water supply
- Electric transmission system

**Step 1**
Low-carbon and low-emission power: petroleum and coal are gasified then separated into hydrogen and CO₂. The hydrogen is directly used to generate electricity in a gas turbine and the CO₂ is transported to a depleted oil field for use in enhanced oil recovery (EOR) operations.

**Step 2**
The closed-loop process enables the re-introduction of carbon back underground: CO₂ is captured at the HECA plant and delivered into a depleted oil reservoir where it is used for enhanced oil recovery and ultimately trapped and stored.

**Step 3**
The CO₂ is injected to a depth of 6,000 ft which is the equivalent depth of four Empire State buildings stacked on top of each other.

**Step 4**
Permanent CO₂ storage: the CO₂ becomes locked in the pore spaces where oil had been trapped for millions of years.
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Oxy CO₂ EOR Project Site Location
Southern San Joaquin Valley

Sedimentary Rocks:
- Pleistocene and Recent
- Miocene and Pliocene
- Paleocene through Oligocene
- Late Jurassic and Cretaceous

Intrusive Rocks:
- Sierra Nevada granitic basement
- Coast Range ultramafic basement complex

ELK HILLS OIL FIELD
LOCATION OF THREE DEEP STEVENS STRUCTURES

geology from Jennings (1977)
oil and gas fields from DOGGR (1998)
31S & NWS Stevens Reservoirs contain:

- 640 active producing wells, 185 active injection wells
- Over 7.5 billion Bbls reservoir pore volume
- Sequestering 20 yrs CO₂ off-take from HECA will require less than 1 billion Bbls reservoir pore volume
What is the CO\textsubscript{2} Water-Alternating-Gas (WAG) Flood Process?
Predictions of CO$_2$ EOR & Trapping via integrated Reservoir Modeling Study

**CO$_2$ EOR Physics**

Water injection (blue) recovers oil in large pores; leaving trapped oil (red) in small pores.

CO$_2$ (yellow) dissolves and displaces trapped oil; leaving only heavy ends (brown) in the reservoir.

Frequently, chase water is injected after CO$_2$. In this case, a significant fraction of CO$_2$ is trapped / retained by the injected water.
CO₂ EOR Results in Sequestration

- During each CO₂ injection cycle, 30 – 50% CO₂ is typically unrecoverable and sequestered with each pass through the reservoir.
- When field no longer produces economic oil/gas rates, all wells will be plugged according to regulations, trapping all CO₂ in the reservoir.

**CO₂ Material Balance – Closed Loop**

**Supplied**
- CO₂ = 115

**Injection**
- CO₂ = 115

**Injected**
- CO₂ = 252

**Producing Reservoir**
- CO₂ = 115

**Produced**
- CO₂ = 137

**Recycled**
- CO₂ = 137

**Operating & fugitive CO₂**
- <0.3%

- All CO₂ data in million metric tons
- Data from Denver Unit CO₂ EOR Project
Major Surface Project Components

- **CO₂ Injection and Recovery Equipment**
  - CO₂ Supply System
  - Satellite Gathering Stations
  - Infield Gathering and Injection Distribution Pipelines

- **Recovered CO₂ Purification and Compression**
  - Central Tank Battery Test (CTB)
  - Reinjection Compression Facility (RCF)
  - CO₂ Recovery Plant (CRP)
  - Produced Water Injection Plant

- **Backup CO₂ EOR Injection Facility**
Outline

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• Site Suitability for Sequestration
• Engineering Study
  – Reservoir characteristics (porosity, permeability, thickness, area, frac gradient, temp., press., saturations)
  – Reservoir fluid data (gravity, viscosity, quality)
  – Casing diagrams all wells (cement fill, cement plugs & evidence no well adversely affects projects)
  – Planned drilling & well work to support project (map of all well locations, purpose & unit boundaries)

• Geologic Study
  – Structural contour map on all injection zones
  – Isopachous map of all injection zones
  – Geologic cross-section through injection well
  – Geophysical logs of all zones & aquifers
Supplements to Class II Requirements

- **Engineering Study**
  - Original reservoir fluid contacts
  - Current reservoir pressure differences
  - Reservoir capacity calculations

- **Geologic Study**
  - Cap rock characteristics
  - Structure defined using sonic imaging
  - Core analysis
  - Geochemical analysis

- **Measurement, Verification and Reporting Plan**
  Being Developed
~2,450 Wells drilled 1998-2009
## Elk Hills Stratigraphic Section

<table>
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<th>AGE</th>
<th>FORMATION</th>
<th>MEMBER / ZONE</th>
<th>RESERVOIR</th>
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<td>Geologic Seal</td>
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### CO2 Target

- N / A
- Monterey
- B
- Shales
- C / D / PG

### Geologic Seal

- Upper Reef Ridge Basal
- N SHALE

### Scalez

- C4D
- C / D / PG
• Reef Ridge Core Analysis
  – Mineralogy
  – Oil Saturation

• Extensive Structural Imaging Data

• Geochemical Analysis
  – Supports Vertical Isolation
Site Suitability Summary

- Comprehensive knowledge of field history & geology
- Stevens reservoirs are ideal for EOR / sequestration
- Class II UIC permit needed
- HECA CO$_2$ sequestration will need to be measured, verified & reported