What’s in a Barrel?

One Barrel = 42 gallons

- Gasoline - 19.5 gallons
- Fuel Oil - 9.2 gallons
- Jet Fuel - 4.1 gallons
- Asphalt - 2.3 gallons
- Kerosene - 0.2 gallons
- Lubricants - 0.5 gallons
- Petrochemicals, other products - 6.2 gallons

Modified from Armentrout, 2002
When Will Peak Production Be Reached?
Future Energy Sources

Modified from Amnentrot, 2002
Future Energy Sources

Modified from Armentrout, 2002
World Wide by 2030

688 Billion Barrels from EOR

vs.

732 Billion Barrels from New Discoveries
Ideal EOR

- Produced Fluids (Oil, Gas and Water) Separation and Storage Facilities
- Production Well
- Carbon Dioxide
- Injection Well
- Water Injection Pump

[Diagram of an oil and gas field with labeled components]
Oil Gravity Vs. EOR Methods

Oil Gravity °API

N₂ & Flue Gas
Hydrocarbon
CO₂ - Miscible
Immiscible Gas
Alkaline/Surfactant/Polymer
Polymer Flooding
Gel Treatments
In situ Combustion
Steam Flooding
Mining

(Modified from J.J. Taber, F.D. Martin & R.S. Seright, 1997)
Oil Recovery Volumes

After Melzer Consulting
CO2 Projects

In the US there are currently 80 projects using CO2 for EOR. They produce 234,000 barrels per day, or 5% of domestic production.
Wyoming Oil Production

Currently about 800 reservoirs produce nearly 52 million barrels annually. The top 25 reservoirs produce approximately 28 million barrels annually (54%).
In Wyoming
51.5 million barrels in 2005
10-15% by EOR
8.5% by CO2 EOR
Wyoming EOR

According to the WGS 8 billion barrels remain in Wyoming fields. Between 5% and 15% of this could be recovered with EOR methods. Only 5% could mean 2 billion dollars for Wyoming over 20 years. At $35.00 a barrel.
Wyoming ends oil slide

Revived production from old fields brings first increase in 21 years

By BOB MOEN
Associated Press writer

CHEYENNE — Wyoming will post its first increase in oil production in 21 years thanks to revived production from old oil fields and new production in southwest Wyoming, said Don Likwartz, supervisor of the state Oil and Gas Conservation Commission.

Likwartz said Thursday that 2006 oil production numbers were still not final, but preliminary numbers show that production last year through November was ahead of 2005 by 735,000 barrels.

Once the December 2006 production numbers are available, Likwartz said, he expects last year's oil production in Wyoming to exceed 52 million barrels. In 2005, the state produced about 51.7 million barrels.

Oil production in Wyoming had been on a downward slide since 1985, when the state produced 131 million barrels.

The reversal is good news for Wyoming coffers because the state collects taxes on oil taken out of the ground.

Likwartz attributed the turnaround in production to Anadarko Petroleum Corp. reviving the Salt Creek oil field north of Casper and to new oil being found in the Jonah and Pinedale Anticline natural gas fields in southwest Wyoming.

The 100-year-old Salt Creek field had been considered all but tapped out until Anadarko began pumping carbon dioxide into the ground a couple of years ago. That forces out oil that could not be recovered by conventional drilling methods.

The CO2 injection is predicted to boost Salt Creek's production from about 5,000 barrels a day now to 30,000 barrels a day by 2010.

In southwest Wyoming, the natural gas development in Jonah and Pinedale in Sublette County has yielded valuable oil as well, Likwartz said.

Oil production in Sublette County has risen from 3.3 million barrels a year in 2000 to 5.1 million barrels in 2005, a 54 percent increase.

Money from oil taxes helps fund schools, cities, towns, highways and water development, among other things.
The Mandate

To conduct research to develop new EOR technologies and to promote EOR in the State of Wyoming through transfer of new and existing technologies.
EOR Commission

Governor Fruedenthal (Rob Hurless)
Charles Townsend—State Senator
Ron Surdam—State Geologist
Bern Hinckley—Consultant
Lynne Boomgaarden—State Lands
Peter Wold—Wold Oil
Gail Chenoweth—Marathon Oil
Jim Neiman—UW Trustee
Eric Nelson—Legal Counsel
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Paul Willhite—University of Kansas
James Griffin—Texas A & M
EORI Outreach Strategy

Information Assembly and Acquisition
- Database Development
- Fracture Characterization
- Reservoir Characterization
- Oil Properties
- Wettability
- Oil Miscibility
- Basin-Scale Scoping

Technical Development
- CO2 Capture
- PVT
- Multi-well Tracer
- Scoping Tool
- Chemical Flooding
- Low Salinity Flooding
- Economic Analysis

Information Transfer
- Cooperative Associations (Project Assistance)
- Contractual Projects

Incremental Oil Production with EOR

Increased State Revenue
EORI Structure

- Geologic Reservoir Model
  - Geologic Data
  - Operator Observations
- Fluid Flow Model
  - Production Data
  - Fluid / Rock Data
  - EOR Strategies
- Production Forecasts
- Economics
- EOR Recommendations to Companies
- Chemical Engineering
- Petroleum Engineering Results
Reservoir Fluids

- CO2 + Gas
- Oil + CO2
- Brine

Rock-Fluid Matrix
Fluid Flow Model
Economics of EOR

Cost Side
- Capital Costs
- Operating Costs

Operating Side
- Prices
- Output
Other Issues

Risk
Social
Environmental

IENR Energy Initiative

Other than technical issues, what are the impediments to enhanced oil recovery in Wyoming and how can they be overcome?
Mechanisms of CO2 Flooding

Swelling crude oils (CO2 is very soluble in high-gravity oils)

Lowering Oil Viscosity

Lowering the interfacial tension between the oil and CO2

Generating miscibility between the oil and CO2 when pressure is above minimum miscibility pressure
Reservoir Conditions

Reservoir pressure greater than minimum miscibility pressure of CO2 and Oil. Reservoir pressure less then fracture gradient. Depth generally greater than 2000 feet.
CO2 MMP and Fracture Pressure in Permian Basin Reservoirs
(edited from Heller and Taber, SPE15001)
As a CO2 ROR Project Proceeds

About 2/3 of the CO2 is Recycled

About 1/3 stays in the reservoir
The amount of CO2 sequestered is 6-10 mcf per incremental barrel of oil. BUT THIS VARIES DRAMATICALLY.
The Most Efficient CO2 Floods
Sequester About the Same
Amount of CO2 As Given Off
by Combusting the Incremental Oil Produced
Less Efficient CO2 Floods Sequester More CO2 Than Is Produced by Combusting the Incremental Oil Produced
i.e. “Green Oil”
Wyoming Oil Production

Currently about 800 reservoirs produce nearly 52 million barrels annually

The top 25 reservoirs produce approximately 28 million barrels annually (54%)
Caveats

To calculate the amount of CO2 needed for an EOR project, each reservoir must be characterized individually.

To estimate the amount of CO2 needed for broad scale EOR, numerous assumptions must be made.

In the following estimate of the CO2 needed for EOR in the top 25 Wyoming reservoirs, it is assumed that all 25 are appropriate candidates for flooding.
Remaining Oil

Cumulative production
Wyoming’s top 25 fields: 4.15 BBO

<table>
<thead>
<tr>
<th>Remaining Oil, in billion barrels (BBO)</th>
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<tbody>
<tr>
<td>50% of OOIP</td>
</tr>
<tr>
<td>4.15</td>
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</tbody>
</table>
CO2 Flooding (WAG) Injectivity

Typical: 5-10% HCPV per year
CO2 Flooding Performance

Graph showing incremental oil production (HCPV) against CO2 + water injection (HCPV) for different locations:
- West Texas San Andres
- Wertz Tensleep
- Lost Soldier Tensleep
Injecting Volume of CO2 based on 1:1 WAG, in trillion cubic feet (TCF) Wyoming’s top 25 fields

<table>
<thead>
<tr>
<th>1 HCPV WAG</th>
<th>1.5 HCPV WAG</th>
<th>2 HCPV WAG</th>
</tr>
</thead>
<tbody>
<tr>
<td>50% Remaining</td>
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<td>50% Remaining</td>
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<tr>
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<td>25_{tcf}</td>
<td>33_{tcf}</td>
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<tr>
<td>75% Remaining</td>
<td>75% Remaining</td>
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</tr>
<tr>
<td>34_{tcf}</td>
<td>51_{tcf}</td>
<td>68_{tcf}</td>
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</tbody>
</table>
Preliminary CO2 Demand Analysis for the Powder River Basin (PRB)

If additional CO2 were available for EOR in the PRB:
How big would the potential CO2 demand be?
What would the potential economic benefits be to Wyoming?
Powder River Basin Study Area
Approach Taken

- Identify “promising” fields
- Fields with >5MMBO cumulative oil production
- Screen for miscibility
- Estimate MMP
- Miscible flood if MMP<fracture pressure
- Estimate CO2-EOR response
- Scaled analog approach (“KM tool”)
- Screen for profitability
Powder River Basin Study Area
The Results of This Analysis of the Potential for CO2 EOR in the Powder River Basin Can be Found Under Research at: http://eori.uwyo.edu
SUMMARY

CO2 Enhanced Oil Recovery Provides:

- Economically Feasible Sequestration Technology Development
- Carbon “Neutral” Transportation Fuels
- Until Alternatives Exist