COALBED METHANE--A NON-CONVENTIONAL ENERGY SOURCE

WHAT IS IT AND WHY IS IT IMPORTANT

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Fueling The Future
25th Annual North American Conference of the USAEE/IAEE
Sept. 20, 2005
Major Growth in Production from Unconventional Resources

- **Tight Gas** - 2.3 bcf in 2004 to 4.1 bcf in 2010
- **CBM** - 1.8 bcf in 2004 to 3.9 bcf in 2010
- **Conventional Gas** - 2.5 bcf in 2004 to 2.3 bcf in 2010

Approx. 42% growth expected across the Rockies

CBM offers the greatest potential with 116% volume growth

Wood Mackenzie
Woodmac.com
RATIO OF HYDROGEN (H) TO CARBON (C) FOR GLOBAL PRIMARY ENERGY CONSUMPTION SINCE 1860 & PROJECTIONS FOR THE FUTURE

- Methane: H/C = 4
- Oil: H/C = 2
- Coal: H/C = 1
- Wood: H/C = 0.1

1935 (midpoint of process)
\[ \Delta t = 300 \text{ years (length of process)} \]
Why Natural Gas?

Efficiency

More New Baseload Electric Plant Costs

...combined cycle gas technology is still the preferred choice

Source: ExxonMobil; Deutsche Bank
COAL-FUELED ELECTRICITY-GENERATING PLANT AND CBM WELL IN UTAH

NATURAL GAS IS A CLEAN BURNING FUEL

PREFERRED ENERGY SOURCE
WHAT IS COALBED METHANE?

METHANE GAS PRODUCED FROM UNDERGROUND COAL BEDS
COALBED METHANE IS FORMED DURING THE CONVERSION OF PEAT TO COAL

Coal is formed from peat over time by heat and pressure.

It all starts with Organic Debris or Peat in a Swamp.

Pressure

Expelled By-Products
- Water
- Methane
- Carbon Dioxide (CO₂)

Heat

Residual Products
- Coal
- Methane
- CO₂

Time
PEAT SWAMP
Picture 28
Cast of an in-situ tree rooted in the Jagger Seam and encased in the crevasse splay deposit that terminated peat deposition in the swamp in the Black Warrior Basin, Alabama. (Picture by Walter Ayers, S. A. Holditch & Associates, Inc., College Station, Texas; shown are William Kaiser (left) and Richard Winston.)
GAS CONTENT OF COALS

GAS CONTENTS OF VARIOUS ROCKY MTN. BASINS

IDEAL RANK

Volatiles driven off

Biogenic methane: Nitrogen Carbon dioxide

Thermally-derived methane

Ethane and other hydrocarbons

LIGNITE

SUB-BITUMINOUS

BITUMINOUS

HIGH-VOLATILE MEDIUM LOW

SEMI META ANTHRACITE

GRAPHITE

Gas content of coals

PODWER RIVER BASIN (<100)
SAN JUAN BASIN (100-500)
RATON BASIN (200-400)
FERRON (UTAH) (400)
APPALACHIA (200-400)

(Scf/t)

after: Kim, 1978
CBM HAS BECOME AN IMPORTANT SEGMENT OF US GAS PRODUCTION

- Conventional Natural Gas: 74%
- Tight Gas Sands: 14%
- Coal Bed Methane: 10%
- Gas Shales: 2%

U.S. CONSUMES 19 TCF OF GAS ANNUALLY
U.S COALBED METHANE PROVED RESERVES, 1989-2003

Source: U.S. Crude Oil, Natural Gas, and Natural Gas Liquids Reserves, 1989 through 2003 annual reports, DOE/EIA-0216.
U.S. CONTAINS 703 TCF OF CBM RESOURCES

- W. WASH 0.7 TCF
- UINTA 3.2 TCF
- SAN JUAN 7.5 TCF
- GRN. RIVER 3.9 TCF
- WIND RIVER 0.4 TCF
- FOREST CITY/CHEROKEE 2.4 TCF
- PICEANCE 7.5 TCF
- RATON 1.8 TCF
- ARKOMA 2.6 TCF
- BLACK WARRIOR
- ILLINOIS 1.6 TCF
- N. APPAL. 11.5 TCF
- CENTRAL APPAL. 3 TCF

PRODUCING
EMERGING PLAYS
IDENTIFIED POTENTIAL
U.S. CBM RESOURCES

• Greater Green River Basin 314 Tcf
• Piceance Basin 99 Tcf
• San Juan Basin 50 Tcf
• Powder River Basin 30 Tcf
• Uinta Basin 10 Tcf
• Raton Basin 10 Tcf

TOTAL 513 TCF
CBM IN U. S. LOWER 48 STATES

- 13 TCF PRODUCED
- 18.7 TCF PROVED RESERVES
- 42.3 TCF ECONOMICALLY RECOVERABLE
- 101.2 TCF UNDISCOVERED
- **703 TCF TOTAL RESOURCE ESTIMATE**
- >14,000 WELLS
- 1.6 TCF PRODUCED IN 2003
- >10% OF U.S. NATURAL GAS PRODUCTION

Data as of 12/03
GAS IS ADSORBED ON INTERNAL SURFACES OF COAL

1 TON OF COAL CONTAINS 1 BILLION SQ. FT. OF INTERNAL SURFACE AREA
Illustration of Major Cleat Providing Flow Path to Wellbore

- Coal Fracture Systems
- Two-Phase Flow in Fractures
- Coal Matrix
Picture 1
Cleats in a coal exposure of the Cretaceous Fruitland Formation in the Star Lake area, southern San Juan Basin, New Mexico. Note the termination of the cleats at a tonstein parting (few exceptions). Both face and butt cleats are well-developed and the butt cleat is iron-stained.
(Picture by Walter Ayers, S. A. Holditch & Associates, Inc., College Station, Texas.)
ADVANTAGES OF COALS AS RESERVOIRS

- Large gas storage capacity
- Shallow depths
- Relatively low cost
- Very good economics
- Most coal basins have been mapped
- Abundant data from logs of older wells
PRODUCTIVE STAGES OF A COALBED METHANE WELL

(1) DEWATERING STAGE

(2) STABLE PRODUCTION STAGE

(3) DECLINE STAGE

VOLUME

TIME
TYPICAL PUMPING UNIT ON A CBM WELL
Exh. # 9  COMPARISON OF GAS PRODUCTION CURVES

GAS PRODUCTION CURVES FOR CBM & SANDSTONE

New technologies improve the time to first production of coalbed methane after the sands in a CBM well begin to play out.
EXAMPLE OF SUCCESSFUL DRUNKARD’S WASH CBM PROJECT

NOTE DECREASING WATER RATES MEANS LOWER OPERATING COSTS

NOTE INCREASING GAS RATES MEANS MORE $$
NUMBER OF WELLS AND DAILY PRODUCTION VERSUS TIME IN POWDER RIVER BASIN

365 BCF/YR

No. of Wells vs Time

MMcfd vs Time

www.eia.doe.gov/
CBM PRODUCTION IN UTAH

Thru April

<table>
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<tr>
<th>Year</th>
<th>Production (MCF)</th>
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<tbody>
<tr>
<td>1995</td>
<td>102.2 Bcf</td>
</tr>
<tr>
<td>1997</td>
<td></td>
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<tr>
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THE CRETACEOUS SEAWAY CONTAINS THE CBM PROJECTS IN THE ROCKIES

RYER, 1988
TYPICAL COAL DEPOSITIONAL ENVIRONMENT
FOR CRETACEOUS ROCKS IN THE ROCKIES

Horne, RMAG 2003
Picture 13

Cyprus trees within the Okefenokee Swamp, Georgia. Note stumps of older trees and succession by younger trees. (Picture courtesy of John Balsley, Consultant, Indian Hills, Colorado.)
MAJOR COAL-BEARING BASINS IN THE ROCKIES
COAL-BEARING CRETACEOUS FORMATIONS

Horne, RMAG 2003
PRODUCTIVE COAL SEAMS IN THE VERY SUCCESSFUL FERRON CBM PLAY OF EAST-CENTRAL UTAH
SCHEMATIC CROSS SECTION
MESAPERDE DEPOSITIONAL SEQUENCE

AN IDEAL “GAS MACHINE”
THE FUTURE LOOKS BRIGHT FOR CBM

ANCIENT SWAMPS

COAL

COALBED METHANE

ENERGY SUPPLY AND