EOR: The Economically Viable CCS Solution

Denbury Resources Inc.

Indiana Center for Coal Technology Research, June 5, 2008

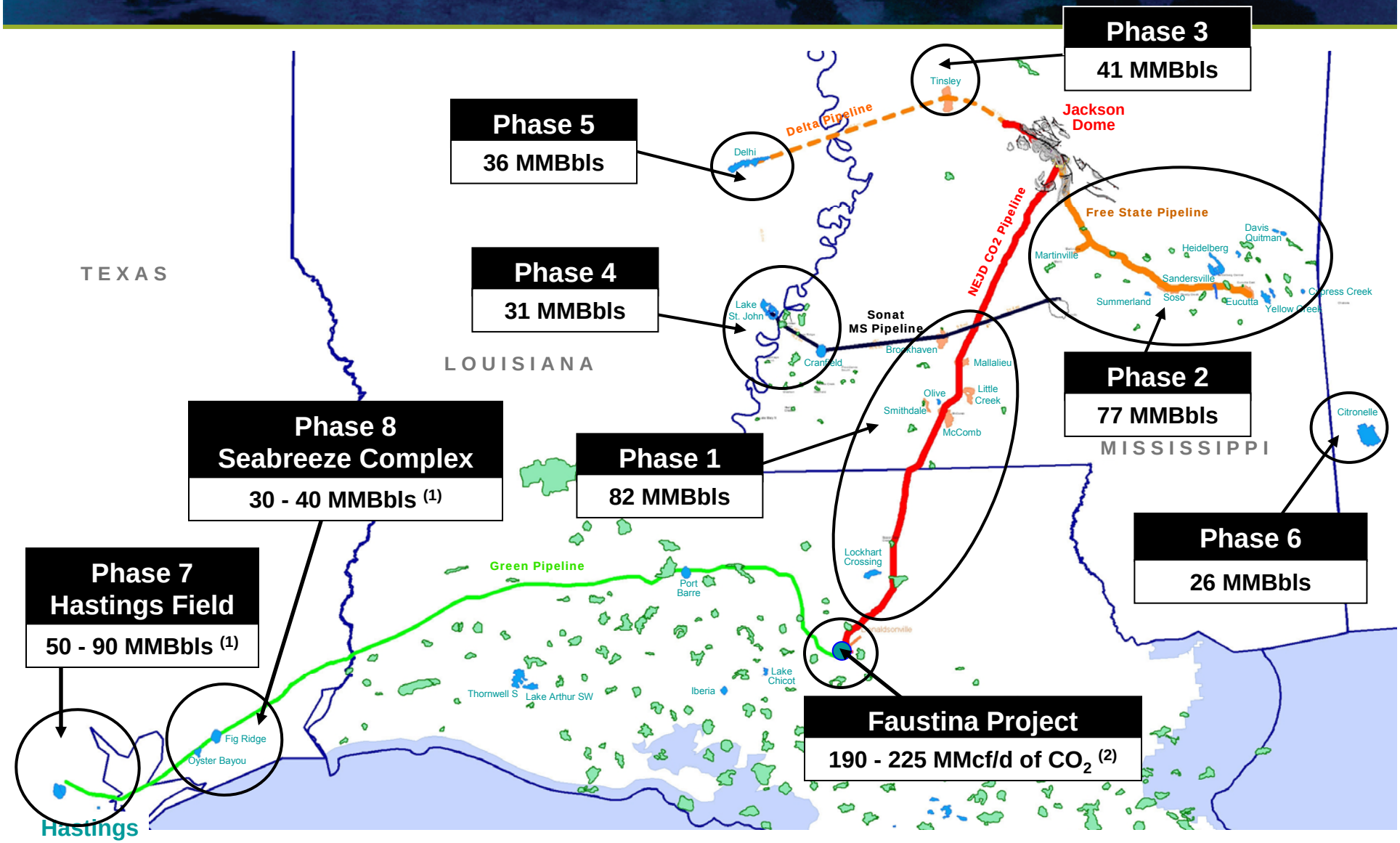
Outline

- **Company Information**
- **The CO_2 Pipeline Dilemma**
- **Carbon Capture and Storage**
- **Issues and Potential Solutions**

Company Snapshot

- **Denbury is the largest oil and gas producer in the State of Mississippi**
- **Primarily as a result of CO_2 enhanced oil recovery and Denbury's efforts, Mississippi's oil production has reversed its decline and is actually increasing**
- **Denbury currently operates nine (9) active CO_2 enhanced oil recovery projects in Mississippi and is in the process of initiating three (3) new floods during 2008**
- **Denbury currently injects approximately 475 MMcf (27,5000+ tons) of CO_2 per day into the nine active floods**
- **Based on our injection volumes we believe we are the largest injector of CO_2 on a daily basis in the U.S.**
- **Denbury currently operates approximately 320 miles of CO_2 pipelines and is in the process of constructing an additional 400 miles of CO_2 pipelines.**
- **Since 1999, Denbury has produced in excess of 20 MMBbls of oil from CO_2 Flooding**

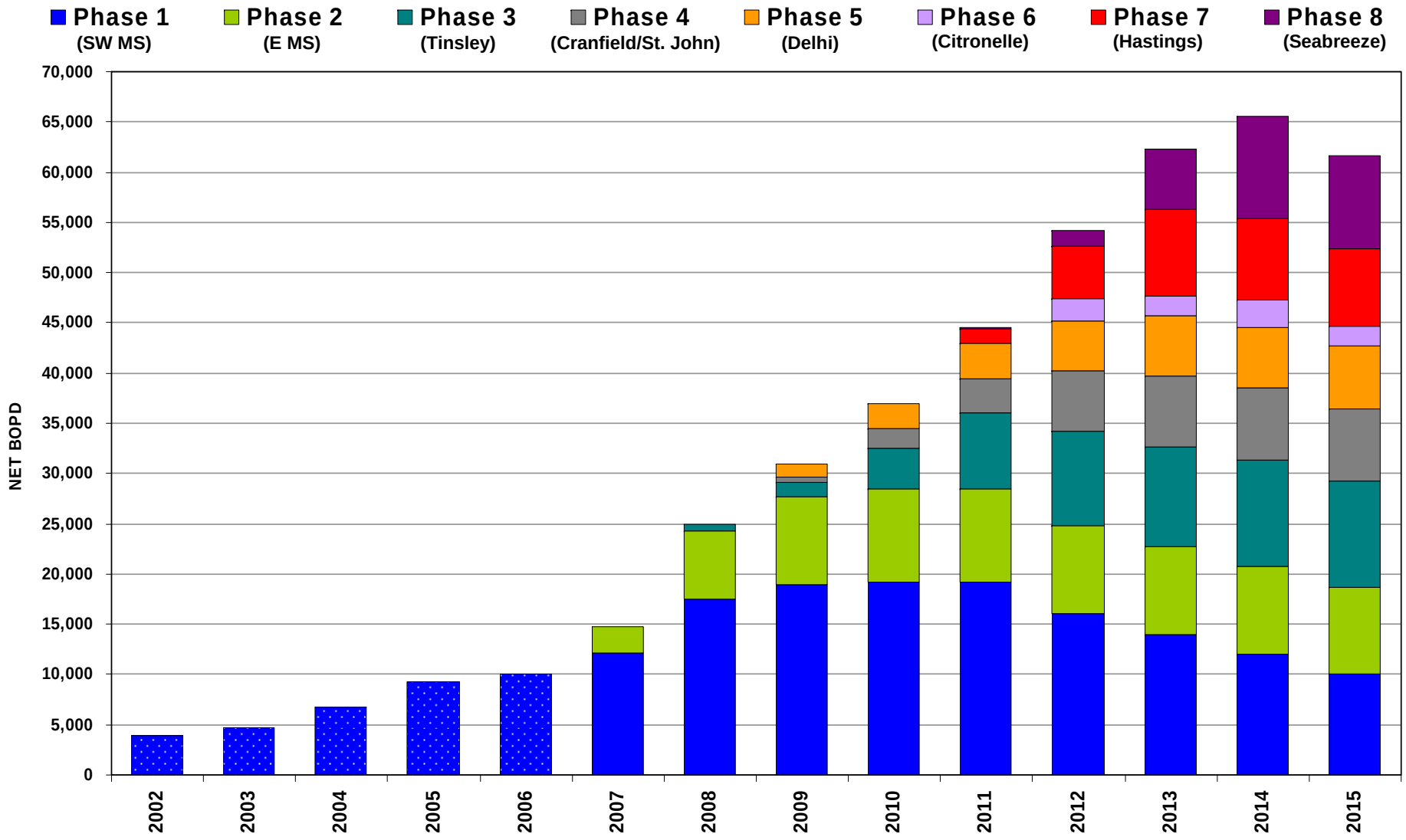
CO_2 Projects - Total Potential Tertiary Oil Reserves [1]



(1) Probable tertiary oil reserves as of 12/31/06 based on 10% to 17% recovery factors. Hastings Field is under contract but not owned.

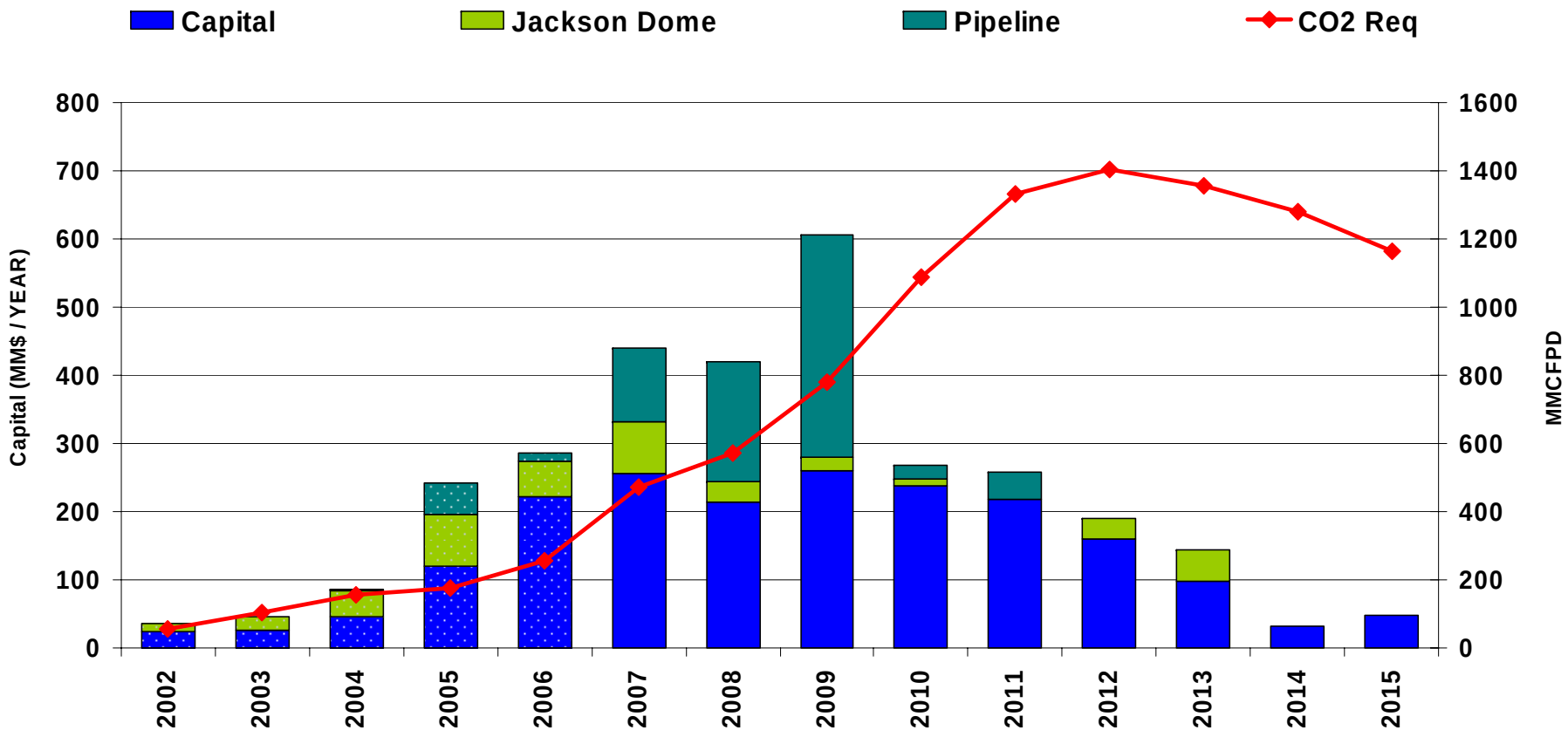
(2) Projected CO_2 production of petroleum coke to ammonia plant expected to be completed during 2010.

CO_2 Business Model – Projected Net Oil Production



Note: Forecast based on internal management estimates. Actual results may vary.

CO_2 Business Model



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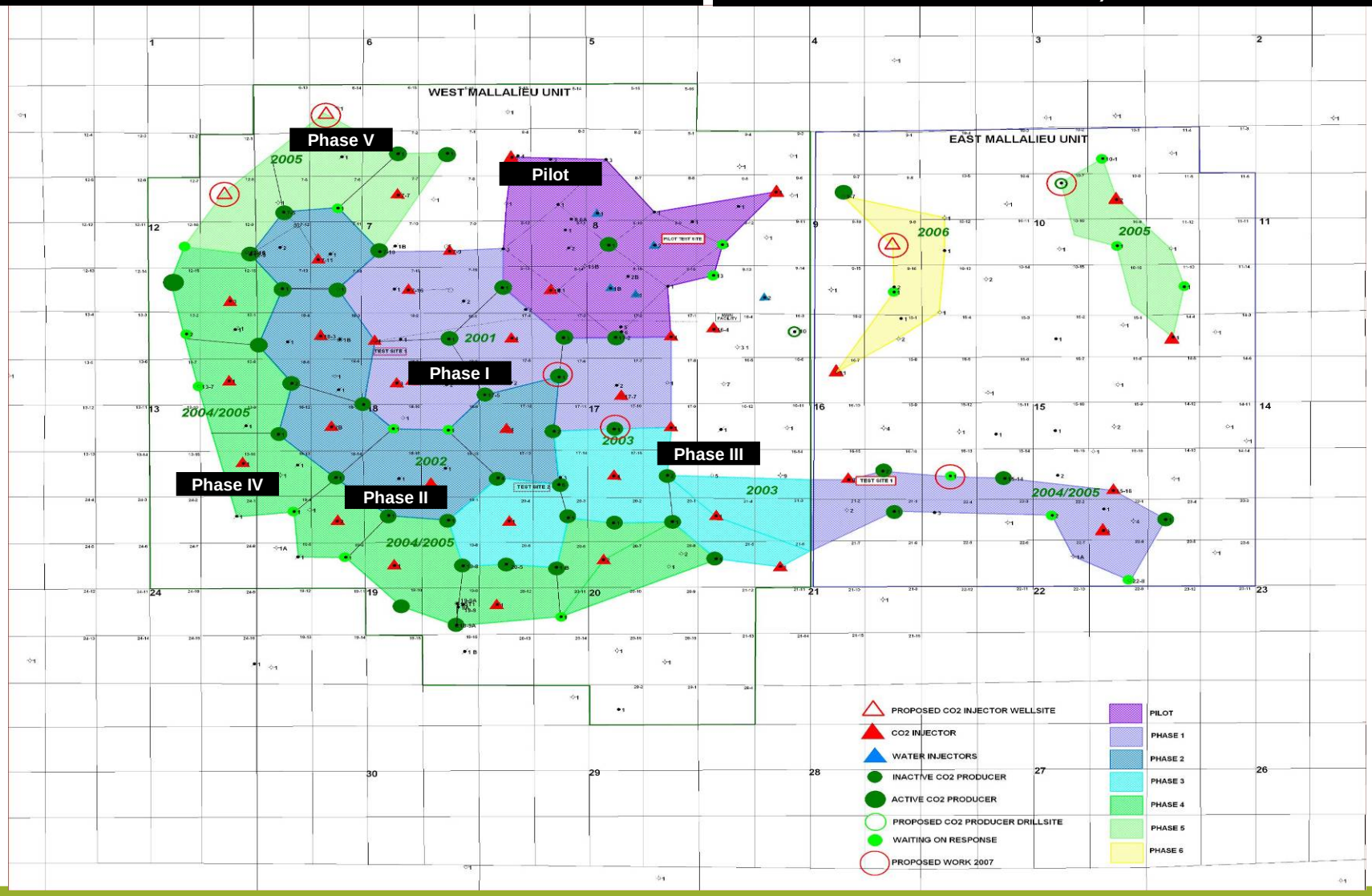
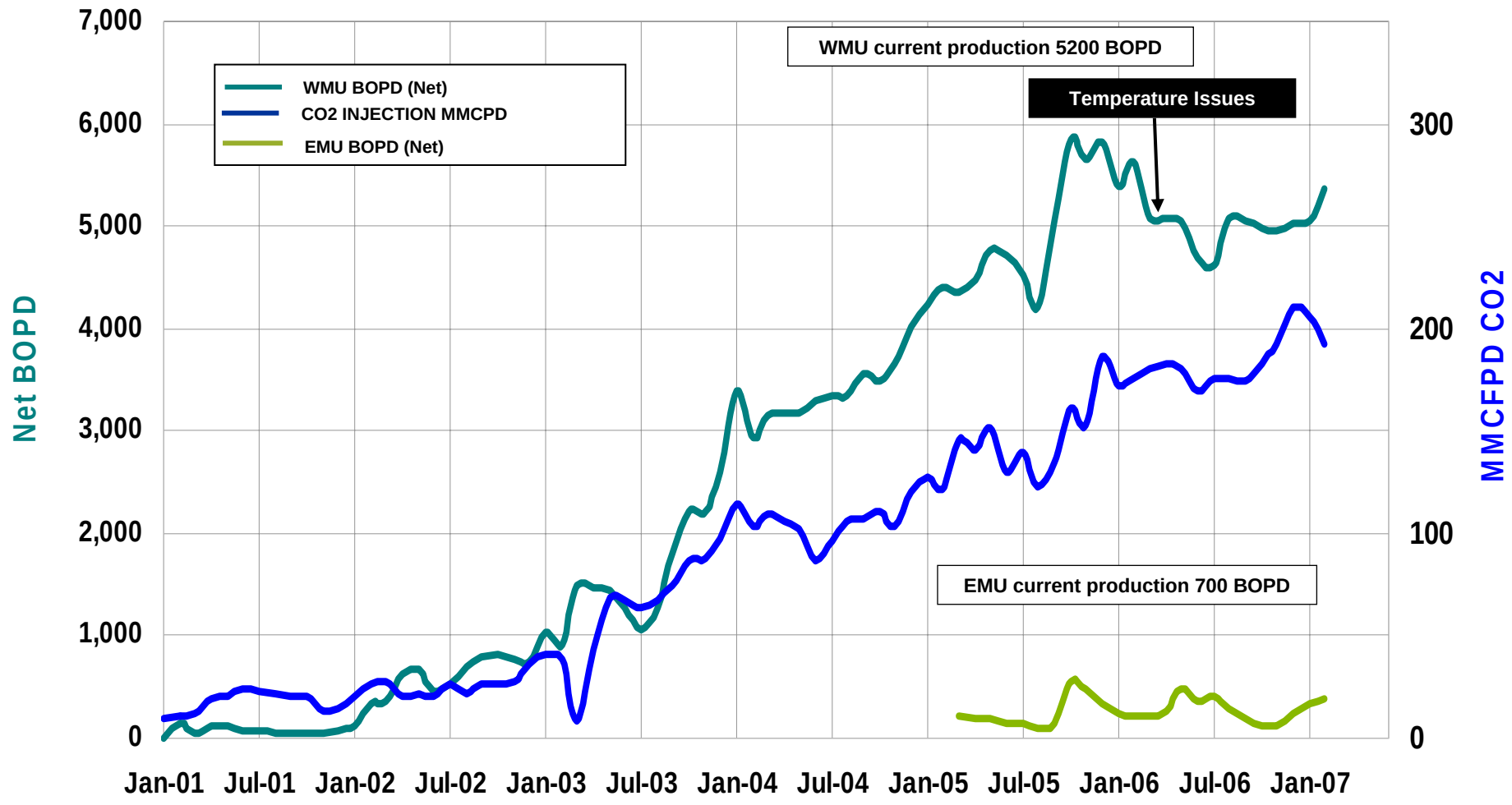
Mallalieu Area

Mallalieu, West Unit: 3,574 Acres | **Mallalieu, East**

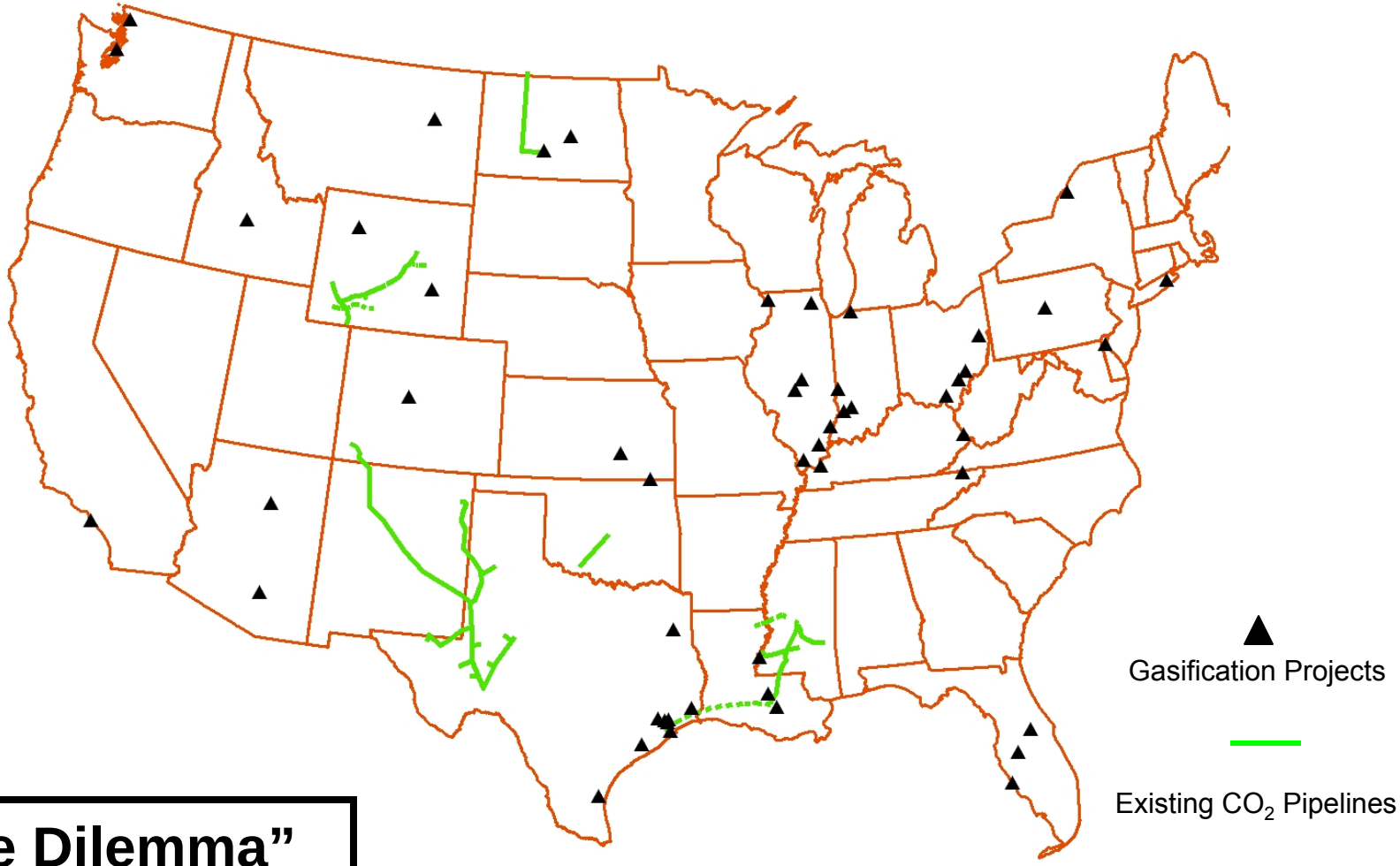


Mallalieu Area

Net Daily Production vs. Total CO_2 Injection



US CO_2 Pipelines vs Gasification Projects



"The Dilemma"

Scoping Economics of a 450 Mile CO_2 Pipeline**

- **30" Pipeline**
  - **Free Flow Capacity – 650 MMcf/d**
  - **Capacity w/ 1 Pump Station – 880 MMcf/d**
  - **Annual Pump Station Expense (w/o repl. costs or power substation) - $7 MM**

- **26" Pipeline**
  - **Free Flow Capacity – 450 MMcf/d**
  - **Capacity w/ 3 Pump Stations – 800 MMcf/d**
  - **Annual Pump Station Expense (w/o repl. costs or power substation) - $19 MM**

- **24" Pipeline**
  - **Free Flow Capacity – 370 MMcf/d**
  - **Capacity w/ 5 Pump Stations – 800 MMcf/d**
  - **Annual Pump Station Expense (w/o repl. costs or power substation) - $31 MM**

*****All Cases Used Pipeline Construction Costs for CO_2 Pipelines in Mississippi***

Compression Capital Costs

- **Stated Conditions**
  - **15 psig Suction to 2100 psig Discharge**
  - **3 - 5800 T/d Compressors**
  - **Purchase Cost - $30 MM**
  - **Installation Cost - $30 MM (based on general construction and installation costs)**
  - **Total Cost - $60 MM**
  - **Total Power Requirement – 82.8 MW**

- **Higher Suction Pressure**
  - **50 psig Suction to 2100 psig Discharge**
  - **Purchase Costs - $22.5 MM**
  - **Total Costs - $45 MM**
  - **Total Power Requirement – 45 MW**

CO_2 Capture Pressure is a Major Factor on Costs for CCS

Total Amortized Cost ($/Mcf)

- **Amortization Schedule**
  - **20 and 30 Years**
  - **Solved for Lowest Cost per Mcf Delivered to the EOR Project**
  - **Attempting to Achieve a Utility Type ROR - 30 Year Schedule**
  - **800 MMcf/d from Day 1**
  - **Two Year Construction Timetable**
  - **Total Capital - $750 M – (24" Pipeline)**

- **Components of Costs – Stated Conditions (15 psig)**
  - **Capital Recovery - $0.475/Mcf**
  - **Operating Costs of Pipeline and Booster Stations - $0.146/Mcf**
  - **Total Costs - $0.621/Mcf**
  - **Excludes Costs of Power to Compress CO_2**
  - **Excludes Cost for CO_2**

Carbon Capture and Storage

- **Basic Assumption: Everyone will be Required to Deal with CO_2 Emissions**

- **The Costs of Capture is the same whether the Emitter Chooses to Ultimately Inject into a Pipeline or Inject into Saline Reservoirs.**
  - **CO_2 Pipelines Operate at Pressures > 2000 psi**
  - **Injection Pressures for Saline Reservoir Injection will most likely be > 2000 psi**

Carbon Capture and Storage – Geologic Example

- **Single Gasification Project Emitting 200 MMcf/d of CO_2**
  - **30 Year Life**
  - **Total CO_2 Emissions – 2.2 Tcf of CO_2**

- **Denbury's DRI Ice Field**
  - **16,000' Underground**
  - **Reservoir Pressure - +/- 11,000 psi**
  - **Areal Extent - 5,500 acres to spill point (Approx: 9 sq. miles)**
  - **Average Thickness - 300'**
  - **Storage Capacity - Approx. – 3 Tcf**

Thus, the areal extent of a single plant's CO_2 emissions will cover a very large area, much greater than the most likely plant site area.

if thickness = 125', Area would be the size of Manhattan (22+ sq. miles)

if thickness = 60', Area would be the size of San Francisco (47+ sq miles)

Carbon Capture and Storage

- **Enhanced Oil Recovery Operations Can Provide the "Costs" of Transportation, Sequestration and Liability**

- **Saline Reservoir Injection - All "Costs" for Transportation, Sequestration and Liability will Remain with the Emitter**

- **Therefore;**
  - **Enhanced Oil Recovery is the Lowest Cost Option for Sequestering CO_2 Emissions Today and for the Foreseeable Future**
  - **Provides an Economic Solution for CCS and Provides Additional Quantities of Domestic Oil Production**
  - **The Only CCS Method that Produces an Economic Benefit and Social Benefits**
  - **The Only CCS Method that can be Utilized Now**

Issues

- **EOR Projects Require Total Delivered CO_2 Costs < $0.50/Mcf at Oil Prices of $30/Bbl to Ensure Its Ability to Continually Take and Sequester the CO_2. Higher Oil Prices will allow CO_2 to be Transported Longer Distances**

- **CO_2 Located Closer to Existing CO_2 Pipeline Infrastructure will have a Considerable Cost Advantage**
  - **No Different than Natural Gas Production**
  - **The Closer Natural Gas is to the User the Higher the Price it Receives (Gulf Coast vs Rockies)**

Solutions

Potential Solutions

- **Greenhouse Gas Emissions Credits – "Carbon Value"**
  - **Estimated 2010 Values - 100% VER @ $3/ton = $0.17/Mcf @$5/ton = $0.285/Mcf**
- **State or Federal Subsidies to Offset Costs (Capital and Operating)**
- **Is there the Possibility that CO_2 Capture is Valued by the Community Whereby the Sale Price of the Gasification Product Can Be Increased to Cover a Portion of the Costs of CCS?**