Feasibility of Partial Upgrading of Athabasca Bitumen

Jim Colyar, Technology Consultant
Colyar Consultants
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STUDY OBJECTIVES

Study Objectives

- ***Develop Relatively Simple, Technically Proven "Field" Technology to Partially Upgrade Athabasca Bitumen***
  - **Produces a Stable, Saleable SCO and a Heavy Hydrocarbon Reject Stream**
  - **Processing Steps Employed Based on Consultants Expertise of Existing Upgrading Processes**

Study Objectives (Cont'd)

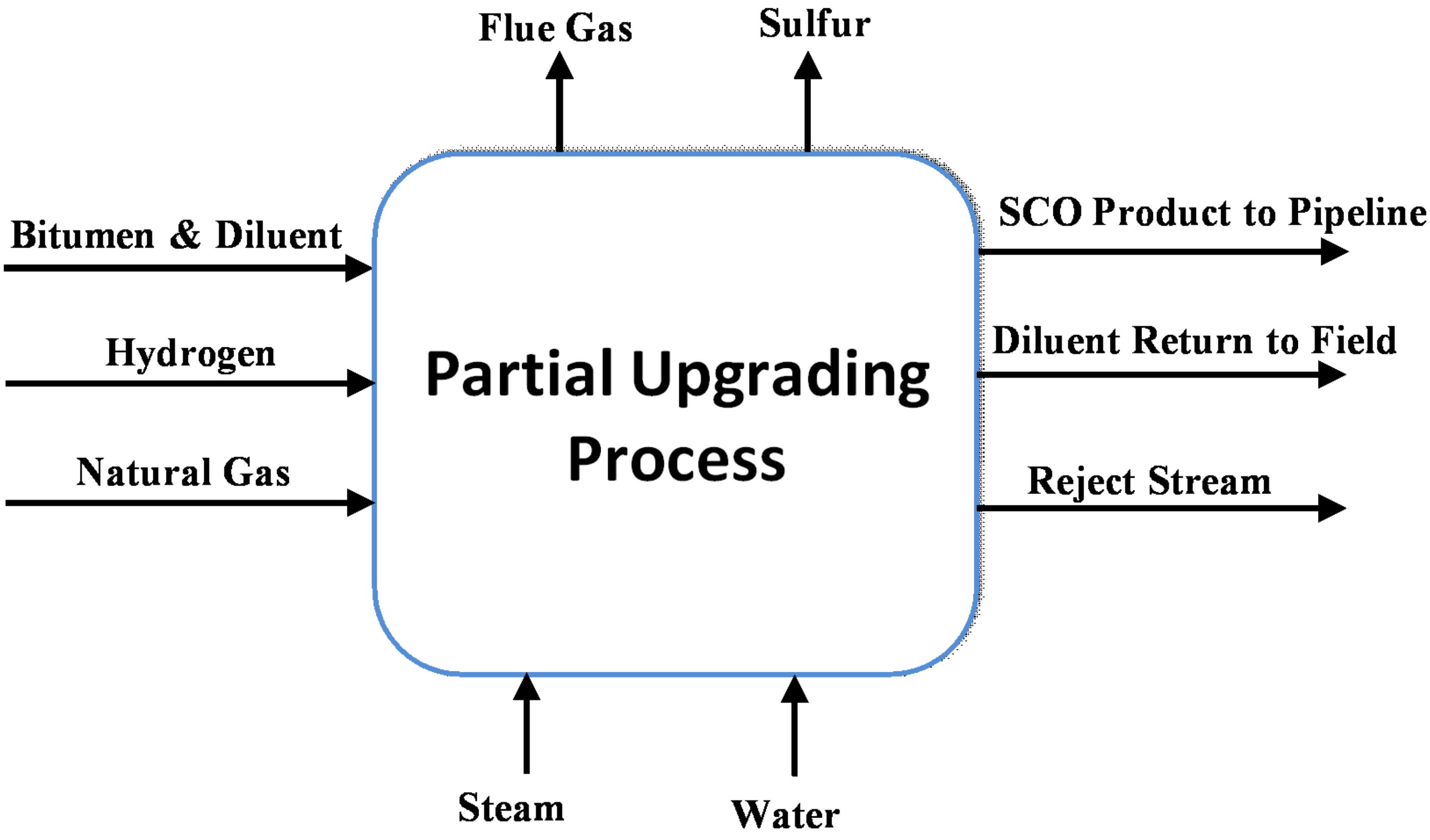
- ***Evaluate Economic Feasibility of Process for Both In-Situ (SAGD) and Mining Projects***
  - **Develop Material and Energy Balances, Investment and Operating Costs**
  - **Integration of Process with SAGD or Mining**
  - **Estimate Profitability and Determine Sensitivity to Light-Heavy Price Margin and Oil and Natural Gas Prices**
    - ***Revenues Compared to DilBit Production***
  - **Develop Process Configuration for Minimizing Carbon Emissions (CO_2 Capture) and Estimate Profitability**

PARTIAL UPGRADING

What is Partial Upgrading?

- ***Objective: Produce Transportable SCO from Heavy Oil Feedstocks***
- ***SCO will Resemble 20°API Heavy Crude***
- ***Typically Implemented in the Field, Near Resource Location***
- ***Characterized by:***
  - **Relatively Low Investment**
  - **Simple Processing Configuration**
  - **Produces Heavy Unconverted ByProduct**
- ***Issues Concerning SCO Value and Stability***

Partial Upgrading Developed by Colyar Consultants



Partial Upgrading Process

- ***Utilizes Proven Processing Steps***
- ***Minimal R&D Required to Validate and Confirm Yields and Costs***
- ***Requires Relatively Small Quantity of Hydrogen***
- ***Completely Eliminates the Need for Diluent***
- ***Results in a 78 V% Yield of Stable SCO***
- ***Bottoms Reject Product can be Utilized for Energy Production***

STUDY BASIS AND CASES INVESTIGATED

Important Parameters and Assumptions - Technical

- ***SAGD Steam to Oil Ratio of 2.5***
- ***Bitumen Production Rate***
  - **SAGD: 50,000 BPSD**
  - **Mining: 150,000 BPSD**
- ***Natural Gas Liquid Used as Diluent for Base DilBit Case***
  - **Blending Ratio of ~40 Bbl Diluent/Bbl of Bitumen**
- ***Partial Upgrading plus Bottom Reject Processing Facility Includes all Offsites and Utilities***

Important Parameters and Assumptions - Economic

- *Western Canadian Location*
- *2010 US $ Basis*
- *Base Light Oil (WTI) Price of $80/Bbl*
- *Natural Gas Price = 50% of WTI Price (Energy Basis) = $6.67/MM Btu*
- *94% On-Stream Time*
- *20 Year Project Life*
- *Investments Include Offsites, Owners' Costs and Contingency*
- *Power Cost of $50/MW-Hr*
- *"Tax" of $30/MT of CO_2 to Evaluate CO_2 Capture Cases*

DilBit and SCO Values

- ***Diluent Price is a Premium over the Light Oil Price***
  - **Premium is a Function of Light-Heavy Oil Margin**
  - **Premium is Typically 5 – 20%**
- ***DilBit and SCO Values are Estimated from Valuation Model***
  - **Estimated Value is a Function of Oil Inspections Including Gravity, Sulfur and Residue Content**
  - **Model Results are Calibrated with Average Historical Data on a Known Crude or Blend (e.g. CLB or LLB)**
  - **Historical Average for DilBit is a 25-30% Differential**
- ***Alternate Case with Small Light-Heavy Oil Margin also Evaluated***
  - **DilBit Set at 90% of Light Oil Price**
  - **SCO Price Estimated at 90 - 100% of Light Oil Price**
  - **Representative of Situation in 2009/2010 Timeframe**

SAGD Study Cases Evaluated

- ***Base Case***
  - **DilBit Production**
  - **Natural Gas Utilized to Produce Required SAGD Steam**
  - **Natural Gas Liquids Used as Diluent**
- ***Case 1 – FBC for SAGD Steam Production***
  - **Partial Upgrading / SCO Production**
  - **Diluent Returned to Field**
  - **Reject Product Sent to Fluidized-Bed Combustor to Produce Steam Required for SAGD**
    - ***Possible Extra HP Steam Used to Produce Power***
  - **SMR Used to Produce Hydrogen for Partial Upgrading**

SAGD Study Cases Evaluated (Cont'd)

- ***Case 2 – Gasification for SAGD Steam and H_2 Production***
  - **Partial Upgrading / SCO Production**
  - **Diluent Returned to Field**
  - **Reject Product Sent to Oxygen Fed Gasifier**
  - **Gasifier Syngas is Split**
    - ***Majority is Combusted to Produce Steam for SAGD***
    - ***Smaller Quantity Used to Produce Hydrogen for Partial Upgrading***
- ***Case 3 – Gasification (IGCC) for H_2 and Power Production***
  - **Partial Upgrading / SCO Production**
  - **Diluent Returned to Field**
  - **Reject Product Sent to Oxygen Fed Gasifier to:**
    - ***Produce Steam for Process (not for SAGD)***
    - ***Produce Hydrogen for Partial Upgrading***
    - ***Produce Significant Power via IGCC***

Mining Study Cases Evaluated

- ***Base Case***
  - **DilBit Production**
  - **Natural Gas Liquids Used as Diluent**
- ***Case 4 - Gasification (IGCC) for Hydrogen and Power Production***
  - **Similar to Case 3 but at Larger Scale**
  - **Partial Upgrading / SCO Production**
  - **Diluent Returned to Field**
  - **Reject Product Sent to Gasifier to:**
    - ***Produce Steam for Process***
    - ***Produce Hydrogen for Partial Upgrading***
    - ***Power via IGCC***

CO_2 Capture Alternate Cases

- ***For Each Case (1 through 4) also Examined Alternate Design where CO_2 is Captured and Compressed***
  - **Case 1**
    - ***OxyCombustion in FBC***
    - ***CO_2 Capture in SMR***
  - **Case 2**
    - ***CO_2 Capture in Gasification Plant***
    - ***Hydrogen Rich (~90%) Stream (from Upstream of PSA) Combusted to Produce SAGD Steam***
  - **Cases 3 and 4**
    - ***CO_2 Capture in Gasification Plant***
    - ***Hydrogen Rich Stream (Upstream of PSA) Sent to Gas Turbine in IGCC to Produce Power***

STUDY RESULTS

Study Results

- ***SCO Yield and Quality***
  - ***Yield of 78 V% on Bitumen Feed***
  - **API Gravity and Viscosity Similar to DilBit**
  - **Lower Residue, Metals, CCR, Sulfur and Asphaltenes**
  - **Stable (Low Asphaltene Content)**
- ***Effect of CO_2 Capture (with $30/MT Tax) also Shown in Each Figure***
- ***Project Investment (See Figure)***
  - **Includes Partial Upgrading and Reject Stream Processing Facilities**
  - ***Lowest Investment for FBC (Case 1), Highest Investment for IGCC (Case 3)***

Study Results (Cont'd)

- ***Net Revenues (over DilBit Production) and Project Pre-Tax IRR Shown in Figures***
  - **Net Revenue is <u>Incremental Revenue</u> to Heavy Oil Producer if Partial Upgrading with Reject Processing is Utilized Instead of DilBit Production**
  - **Net Revenues are:**

    Partial Upgrading Revenues (SCO Sales)

    - Partial Upgrading Operating Costs

    - DilBit Gross Revenues (DilBit Sales)

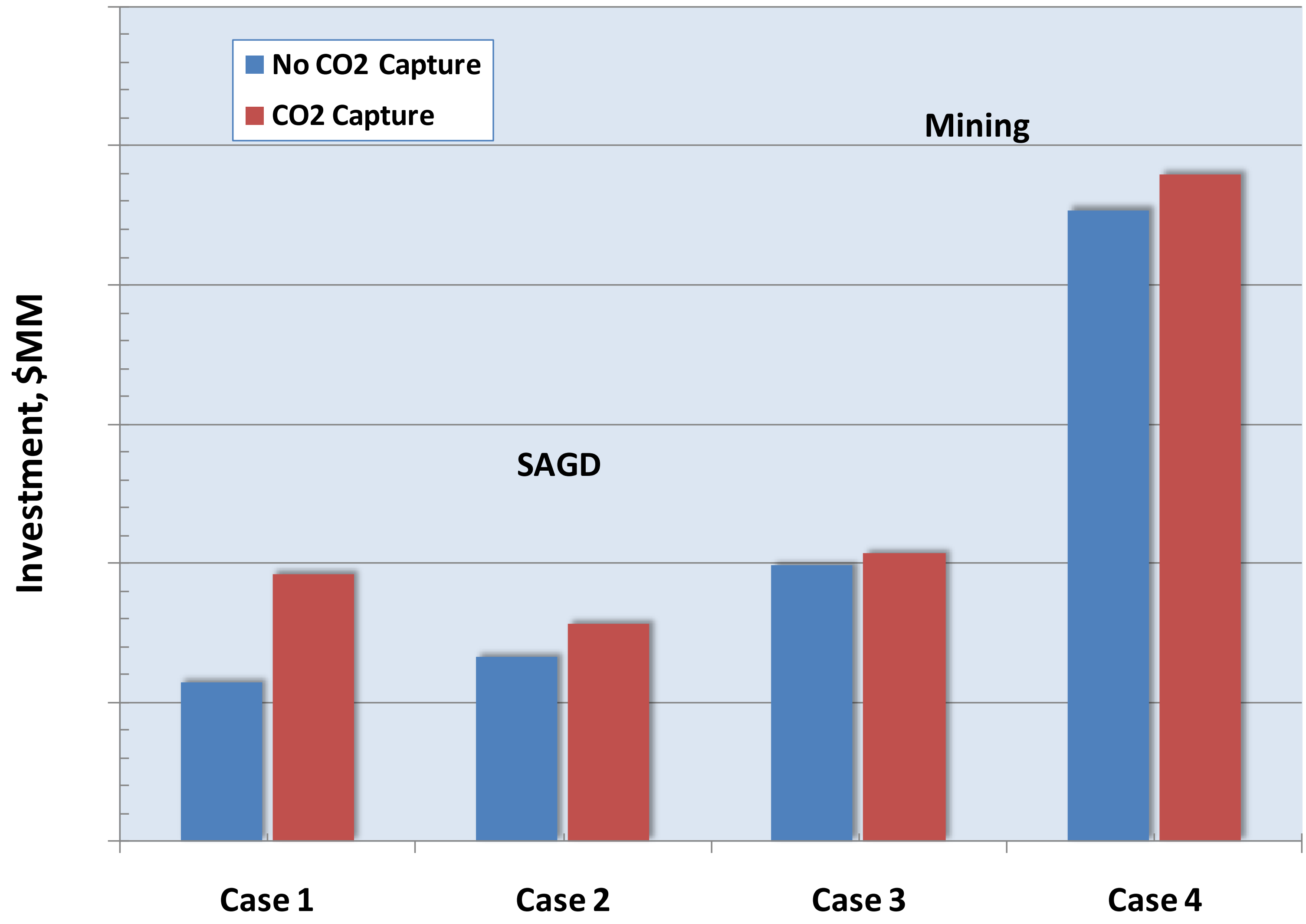
    + DilBit Diluent Cost

    + DilBit Natural Gas Cost (if SAGD Steam Produced via Reject Processing)

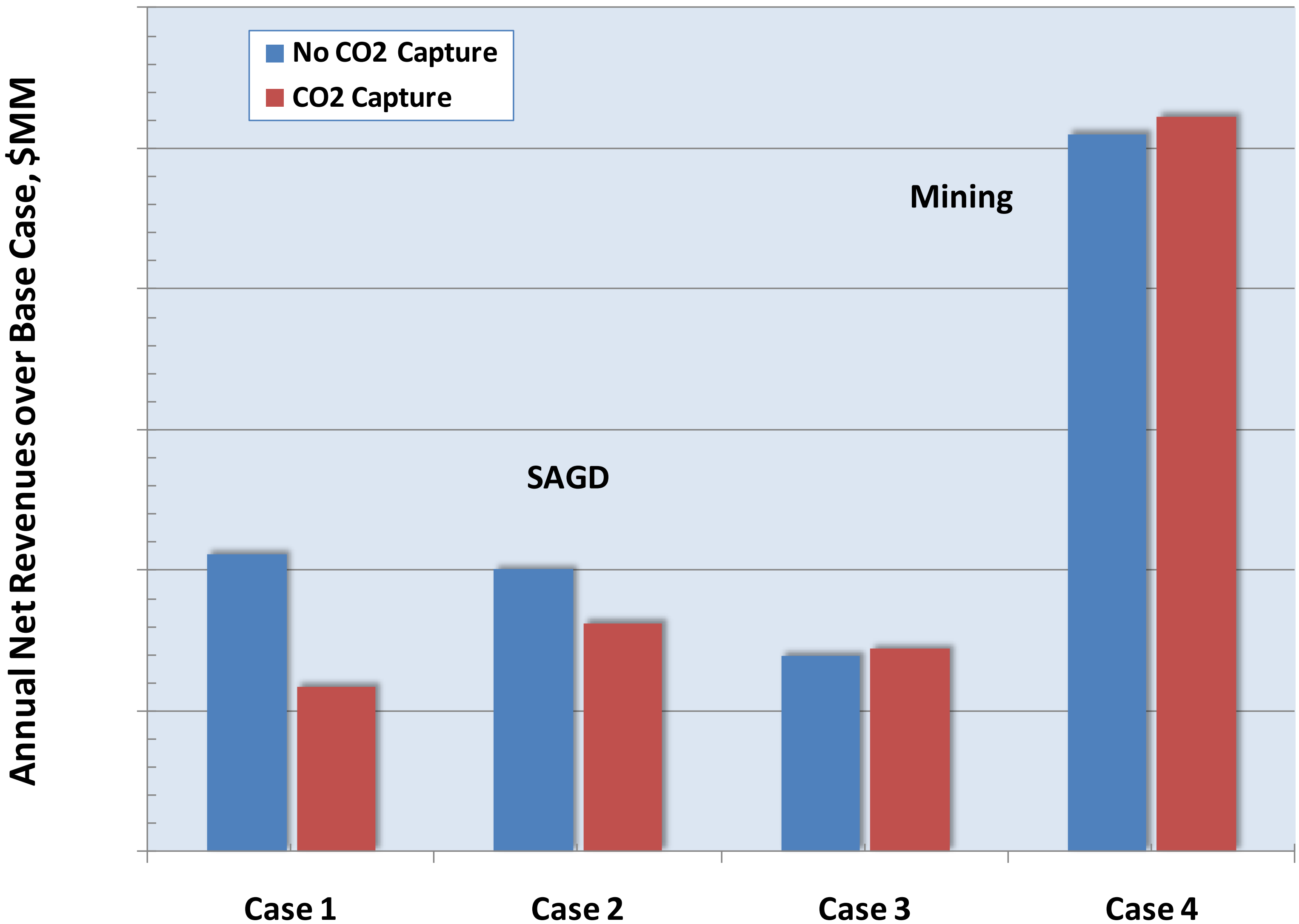
Bitumen, DilBit and SCO Inspections

Inspection	Bitumen	DilBit	Study SCO
Gravity, °API	7-9	20	19
Viscosity@4°C, cSt	-	<350	<350
Sulfur, W%	5	3.9	2.3
Vacuum Residue, V%	56	43	42
CCR, W%	16	12	5
Nickel + Vanadium, Wppm	300	80	50
Asphaltenes, W%	11	8	<1

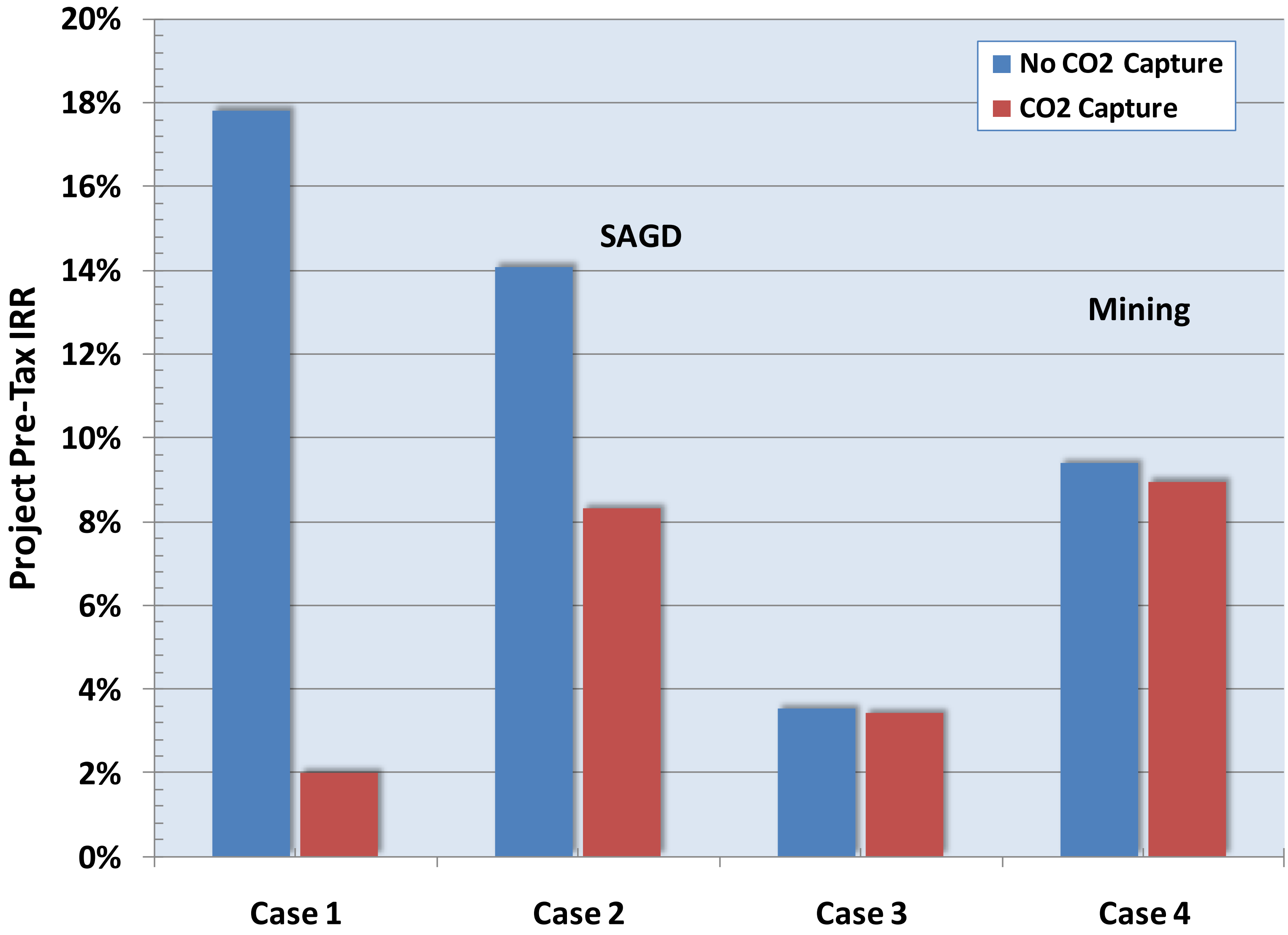
Estimated Investment



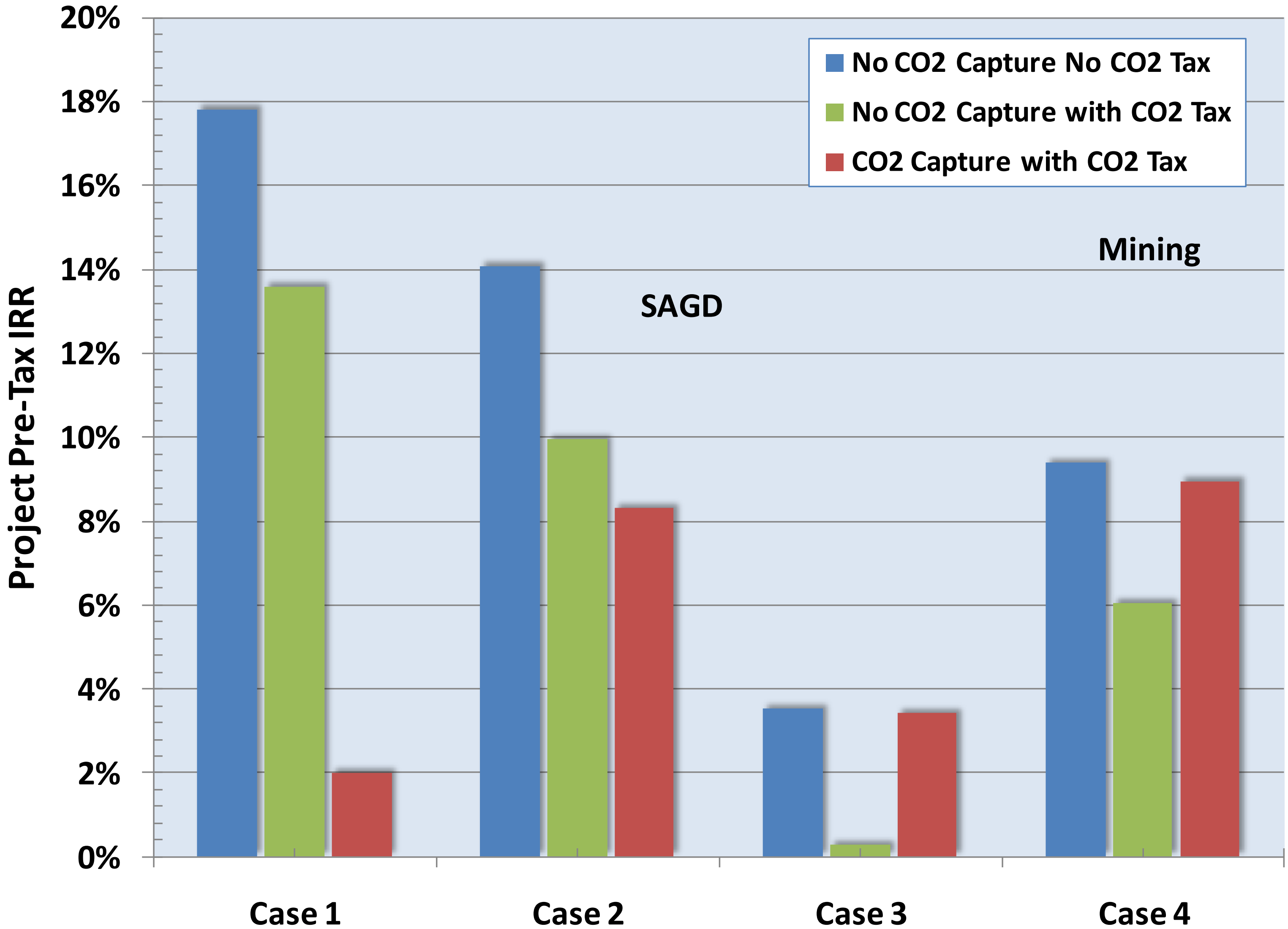
Annual Net Revenues Over Base Case



Project Pre-Tax IRR



Project Pre-Tax IRR Including Consequence of Tax w/o Capture

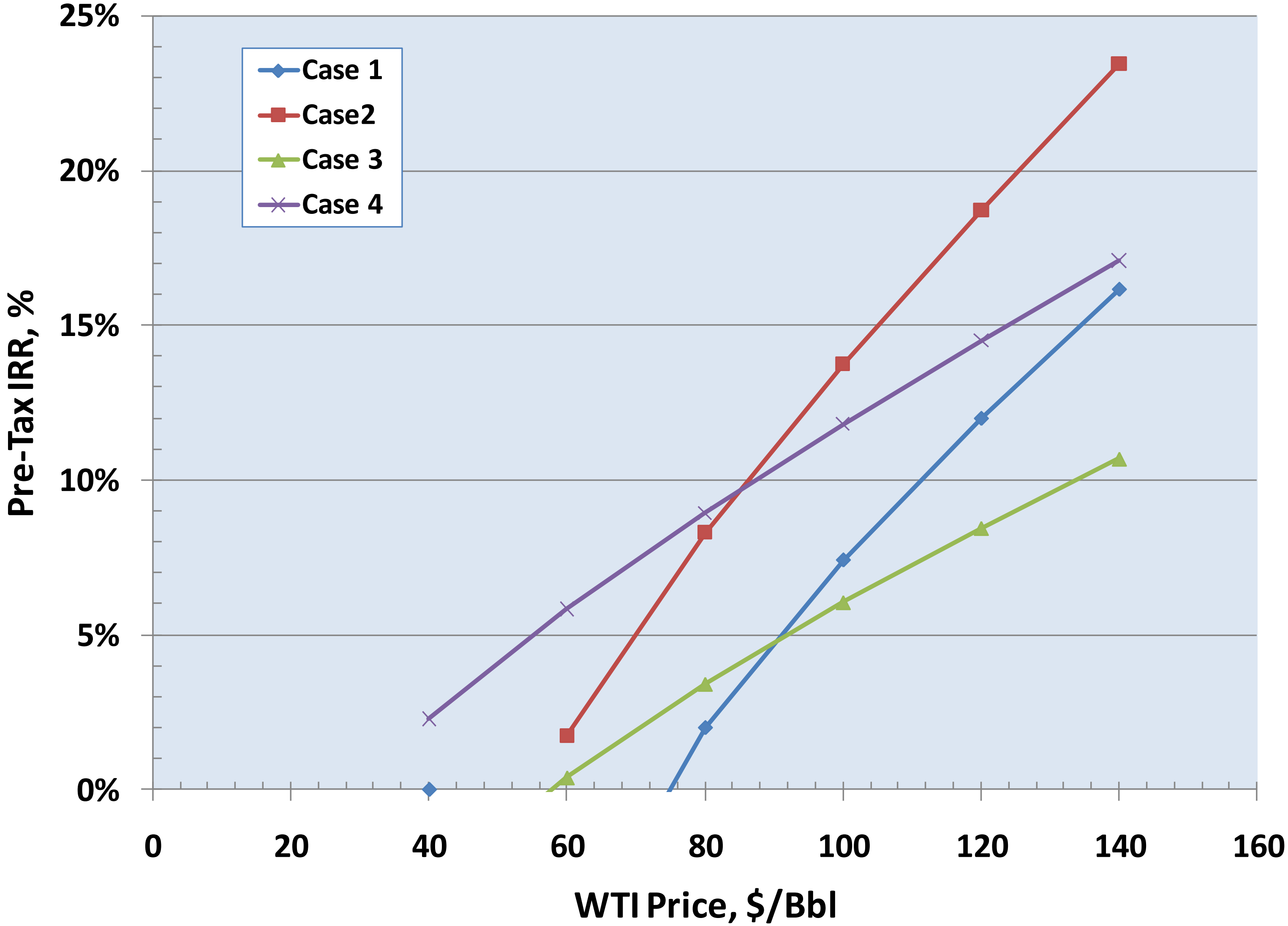


SENSITIVITY STUDIES

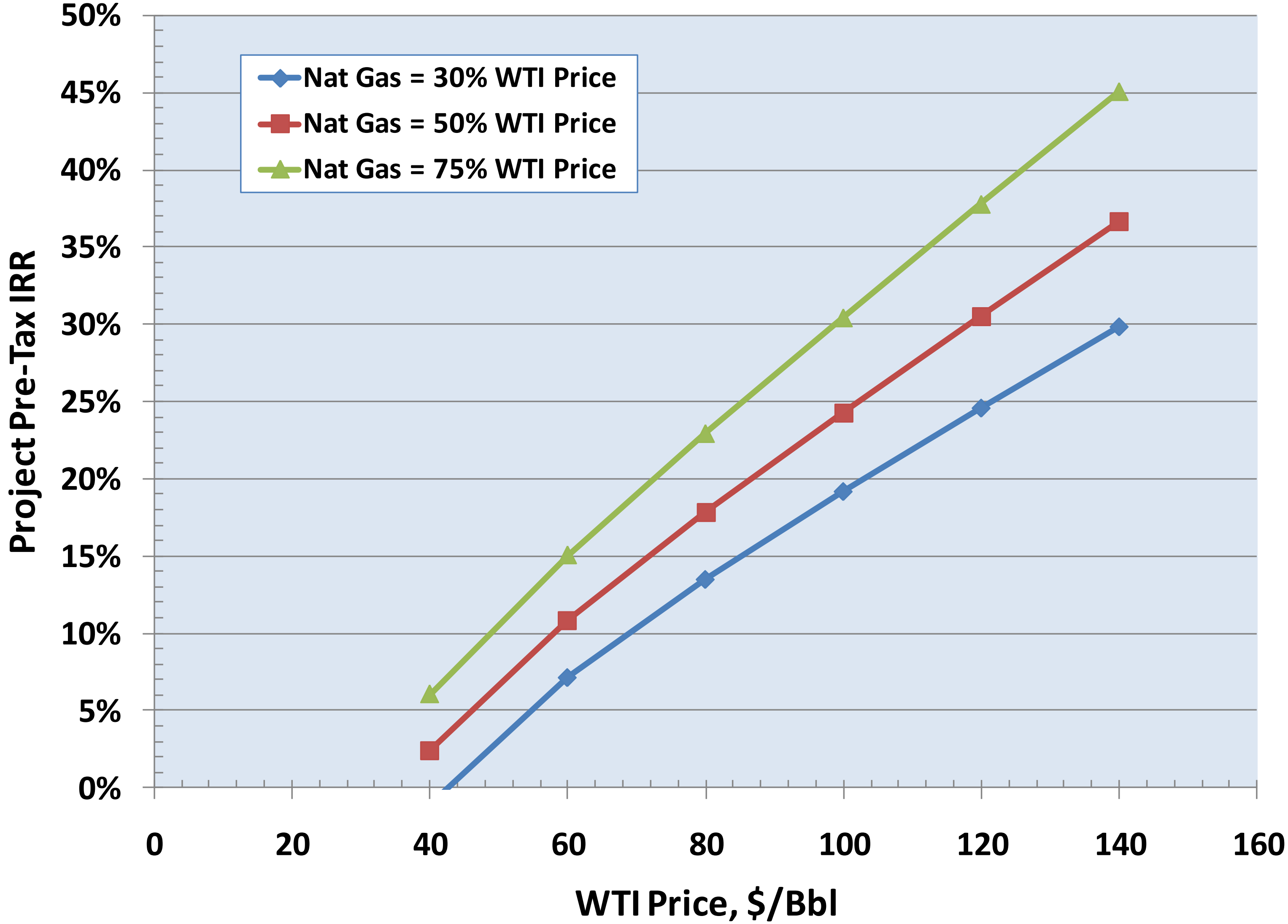
Parameters Investigated

- ***IRR vs.WTI Price***
  - **Also Affects Natural Gas Price since Study Gas Price is Set as a Percentage of WTI**
- ***IRR vs. Assumed Natural Gas Price as a Percentage of WTI Price (Energy Basis)***
  - **Values of 30, 50 and 75% Investigated**
- ***Net Annual Revenues at Small Light to Heavy Oil Price Differential***
  - **Heavy Oil (LLB Type) at 90% of Light Oil Price**
    - ***Nearly All Cases have Negative Net Revenue when Compared to Base DilBit Case***

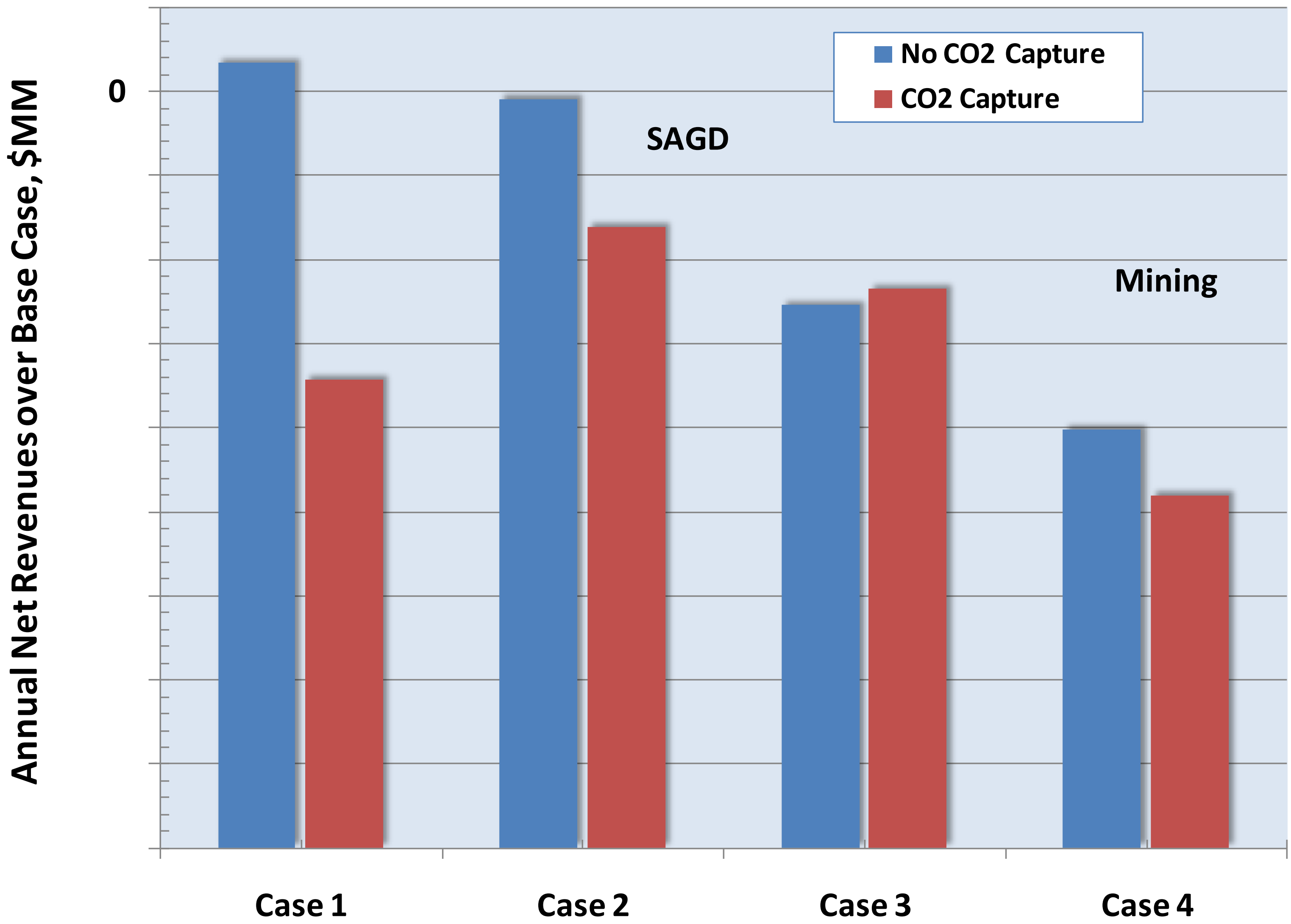
IRR as a Function of Oil Price CO_2 Capture (Tax) Cases



Case 1 (No CO_2 Capture) IRR as a Function of Oil & Gas Prices



Annual Net Revenues – Small Light-to-Heavy Oil Margin



STUDY FINDINGS & ADDITIONAL DETAILS

Important Findings SAGD Project

- ***Partial Upgrading can be Profitable (IRR>10%) with WTI at $80/Bbl, Natural Gas at 50% of WTI Price and Light-Heavy Margin at Historical Averages***
  - **Either FBC or Gasification of HC Reject Stream**
  - **Integrated with Upstream SAGD to Produce Required Steam**
- ***Power Production (IGCC) from HC Reject Stream Indicates Lowest IRR***
  - **Not Economical Feasible at SAGD Scale (50,000 BPSD)**

Important Findings SAGD Project (Cont'd)

- ***Higher Oil Prices Result in Higher Project Revenues Relative to DilBit Production***
  - **IRR Nearly Doubles at $120/Bbl WTI Price**
- ***In a Carbon Tax Environment***
  - ***Without Carbon Capture (Pay Tax): FBC of HC Reject Stream is Favored over Gasification***
  - ***With Carbon Capture: Gasification of HC Reject Stream is Favored over Oxygen fed FBC***
- ***With a Small Light-to-Heavy Oil Margin, DilBit Production is Favored***

Important Findings Mining Project

- ***SCO Production and Significant Power Production from Partial Upgrading Reject Stream (via IGCC) has Approximate 10% Return***
  - **Not Significantly Affected by Natural Gas Price**
- ***Similar Profitability for Carbon Capture/Tax Situation with Approximately 5% Incremental Investment***
- ***With a Small Light-to-Heavy Oil Margin (i.e. 10%)***
  - **Large Revenue Loss When Compared to DilBit Production**

For Additional Information

- ***Detailed Study Report can be Purchased from Colyar Consultants***
- ***Study can be Customized for:***
  - **Specific Crude and Feedrate**
  - **Alternate Bottoms Reject Use**
  - **Upstream Requirements**
  - **Economic Parameters**