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Feasibility Study on CO_2 EOR of White Tiger Field in Vietnam

(CO_2 Capture from Phu-My Power Plant)

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Objectives

- Assess the technical and economic feasibility of CO_2-EOR for the Basement reservoir.
  - What is the cost for CO_2 capture and transportation?
  - Can CO_2-oil miscibility be achieved?
  - What incremental oil recoveries can be achieved?
  - What are the operational requirements?
  - What are the economics?

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Methodology

- Facilities engineering studies (CO_2 capture, pipeline, recycle)
- Laboratory Studies
  - Minimum Miscibility Pressure (MMP)
- Reservoir Simulation
  - Calibrated sector model with CO_2 – EOR performance forecasts
- Economic Analysis

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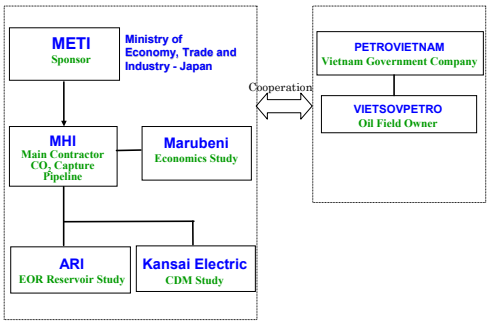
Participants of the Study



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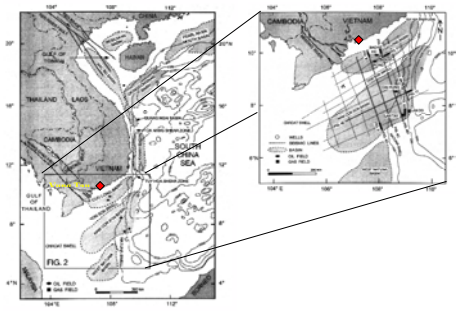
White Tiger Field in Vietnam



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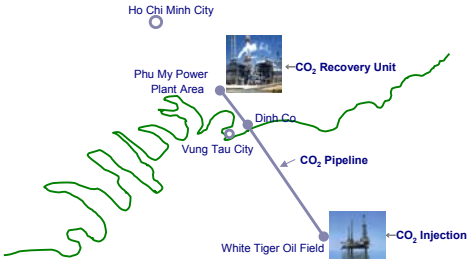
Location Map



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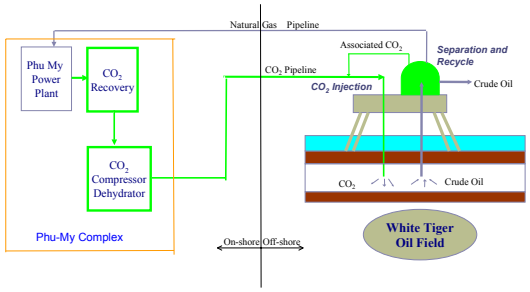
Overall Plan of EOR



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CO_2 Capture and Compression

- **Phu-My Power Plant (No. 1 to 4)**
  - **Location: 70 km South-East from Ho-Chi-Minh City**
  - **Owner: EVN(Electricity of Vietnam)**
  - **Type: Gas turbine combined cycle**
  - **Fuel: Natural gas**
  - **Total Capacity: 4,000 MW**
  - **CO_2 in Flue Gas: approx. 3 vol.-%**
  - **CO_2 availability: 35,000 ton/d**
- **CO_2 Capture and Compression**
  - **Solvent & Process: KS-1**
  - **CO_2 Purity: 99.9 %**
  - **Capacity: 3,000 ton/d/unit x 10 units**
  - **Compressor discharge press.: 2,000 psig**

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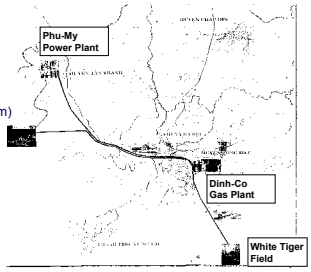
Pipe Line Route

- Route: Along the existing natural gas pipe line, owned by Petrovietnam Gas Company
- Distance: Total 143.6 km (Onshore 37.1 km + Offshore 106.5 km)
- Pipe size: 16" for phase-1 (9,000 t/d) 20" for phase-2 (21,000 t/d)



Existing gas pipeline

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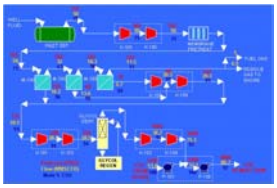
Offshore Facilities

- CO_2 Injection pumps
- CO_2 Injection wells and Oil production wells
- Gas/Liquid Separator
- Membrane separators of CO_2 from the associated gas
- Compressor for re-injection of the recycled CO_2
- Platforms
- Subsea pipelines for transfer of fluids between platforms



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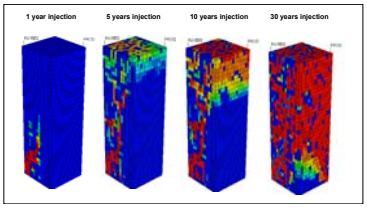
Simulation of CO_2 EOR

- **Laboratory Test**
  - MMP (Minimum Miscibility Pressure) Slim Tube Test
- **Modeling**
  - 1/4 5-Spot Sector Model
  - 16-Component Compositional Model



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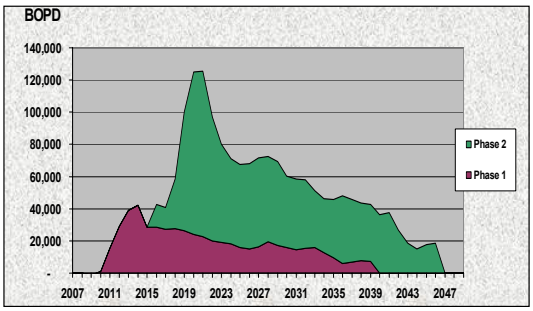
Anticipated Incremental Oil Recovery



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Economic Analysis Assumptions

- Two-phase development:
  - Phase 1: 9,000 tons/d beginning in 2009, bottom-up.
  - Phase 2: 21,000 tons/d beginning in 2016, bottom-up.
- All CO_2 sourced from Phu-My industrial complex, and captured using Kansai/MHI's KS-1 technology.
- Two pipelines required:
  - 9,000 tons/d capacity (Phases 1)
  - 21,000 tons/d capacity (incremental Phase 2)
  - CO_2 delivered to platform as a liquid (>1,200 psi)

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Economic Analysis Assumptions
(continued)

- New platforms and facilities required for CO_2 separation and recycling; new inter-platform gathering and injection pipelines also required.
- Some new wells required for CO_2 injection.
- Existing production wells to be worked-over for CO_2 service; some new wells also required.
- All CO_2 captured at Phu-My to be injected, recycle volumes are additional.

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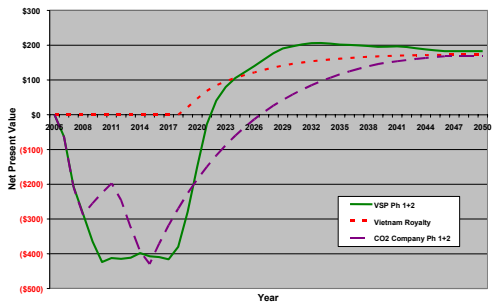
Economics of EOR Business



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Conclusions

- Miscible CO_2-EOR at the White Tiger field is technically feasible. Laboratory measurements have verified the reservoir oil and CO_2 are miscible at pressures above 29 MPa. At present, the lower half of the reservoir is above the MMP but the upper half is below the MMP.
- Incremental oil recovery factors of +/-21% (of OOIP) are predicted with gravity-stable CO_2-EOR.
- The results of an economic evaluation indicate a total NPV to VSP, a CO_2 supply company and the State of Vietnam of more than US$500 million would result.
- If implemented, the project has the potential to sequester in excess of 350 million tons of CO_2.