Lifecycle Energy Modeling
Input into Upstream Design Process

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## Agenda

### Background
- energy usage profile of upstream industry
- upstream conceptual design process
- typical conceptual design case generation

### Design input
- production profile
- valuation methods

### Comparison
- energy intensity vs. production
- CO₂ emissions vs. production
- availability model output

### Conclusion
- net savings achieved – life cycle
- net savings achieved – totals
- questions
Background
Energy usage profile of upstream industry

Top Energy Intensive Industries (worldwide, 2005)

- Upstream and Midstream: 25.28
- Iron and Steel: 20.32
- Refining: 17.23
- Petrochem and Chemicals: 14.25
- Cement: 7.78

Oil and gas is top industrial energy user

Upstream use primarily in pumping/compression
Background
Typical facility conceptual design process

Stage gate process
method of capital appropriation

Assess phase (0.1% of project capital)
develop concept design cases
generate high level definition
target +/-50% cost estimate

Select phase (1% of project capital)
refine and select base case
front end engineering work
target +/-30% cost estimate

Define phase (10% of project capital)
detailed engineering
target +/-10% cost estimate
Background

Typical concept design case generation

- Base process requirements
  - 2 stage separation with OTU
  - 3 stage separation
    - Sales gas let down from terminal stage
    - Separate lift gas compressor
      - Air cooling
      - Indirect seawater cooling
        - Seawater $T_{\text{max}}$ 85°F
        - Seawater $T_{\text{max}}$ 65°F
          - Centralized electric plant with motors
          - Discrete turbine drives
            - All GoM construction
            - Subs constructed in Europe
              - 4 leg full size TLP
              - 4 leg mini TLP
              - 4 leg mid size TLP
              - 4 leg Semisub
              - FPDSO
              - Truss Spar

Candidate for further study
Rejected
Design input
Production profile

Production Profile

- Oil Production
- Produced Water
- Injected Water
- Gas Production

Production Year

kBPD

MMSCFD
<table>
<thead>
<tr>
<th>Design input</th>
<th>Valuation methods</th>
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<tbody>
<tr>
<td><strong>Fuel usage</strong></td>
<td>cost avoidance of fines associated with flaring</td>
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<td>discounted NPV assuming future local gas market</td>
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<td>average pricing for recent gas sales or fraction thereof</td>
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<td>2009 average wellhead gas price $3.71/kscf</td>
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<td><strong>CO₂ emissions</strong></td>
<td>primarily cost avoidance of emissions taxes</td>
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<td>possible offsets market for international companies</td>
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<td>discounted NPV for countries with future requirements</td>
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<td>EUA December 2010 contract was €15.10/ton CO₂ (5/28/2010)</td>
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<td><strong>Availability</strong></td>
<td>calculate actual production time out of service</td>
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<td>use production pricing and profile for value</td>
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<td>compare NPV for base output and for increased availability</td>
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<td>NPV difference is value of deferred production</td>
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<td></td>
<td>Brent spot was $72.40/bbl (5/28/2010)</td>
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<td><strong>Inflation</strong></td>
<td>2.5% annually</td>
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Comparison
Energy intensity vs. production

Annual Average Energy Intensity vs. Production

Energy Intensity (%)

Daily Oil Production (kbpd)

Production Year

GT
VSD
Production

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Comparison
CO₂ emissions vs. production

CO₂ Emissions vs. Production

- GT
- VSD
- Production

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Comparison
Availability model
Conclusion
Net savings achieved, life cycle

Constituent Values of Life Cycle NPV Savings (VSD vs. GT)

- Availability Increase
- CO2 Emission Reduction
- Fuel Usage Reduction
Conclusion
Net savings achieved, totals

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<tr>
<th></th>
<th>GT</th>
<th>VSD</th>
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<tbody>
<tr>
<td>CAPEX (total platform installed cost)</td>
<td>1,149,163,400</td>
<td>1,183,251,600</td>
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<td>(34,088,200)</td>
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<td>NPV OPEX savings for fuel gas</td>
<td>9,304,509</td>
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<tr>
<td>NPV OPEX savings for emissions</td>
<td>1,925,837</td>
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<tr>
<td>NPV OPEX savings for uptime</td>
<td>62,315,457</td>
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<td>Total NPV savings</td>
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<td>73,545,804</td>
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<tr>
<td>Overall savings</td>
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<td>39,457,604</td>
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Questions?