Sustainable Development and Design of Marcellus Shale Play in Susquehanna, PA

By

Sunghae Sidonie
Safa Rohan Hemant B.T. Armstrong

04-07-2009
Agenda

- Design Process Chart
- Acquiring Land
- Drilling, Completion and Fracturing
- Gas Gathering and Processing
- Gas Transmission
- Sustainable Development
- Economic Analysis
- SWOT
- Conclusion
## Lease Cost

<table>
<thead>
<tr>
<th>Year</th>
<th>0</th>
<th>7</th>
<th>14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lease Cost ($/acre)</td>
<td>1500</td>
<td>1500</td>
<td>1500</td>
</tr>
<tr>
<td>Land Leased (acre)</td>
<td>50,000</td>
<td>50,000</td>
<td>50,000</td>
</tr>
<tr>
<td>Total cost</td>
<td>$75,000,000</td>
<td>$75,000,000</td>
<td>$75,000,000</td>
</tr>
</tbody>
</table>
From literature review,

- Land usage varies with gas well type, terrain, location and service companies \(^{(1),(2)}\).
- Focus on the data from operating companies in Marcellus, especially Northeastern area of PA \(^{(3),(4)}\).
- 130~150 acres land is used for a single 3500~4500 ft-long lateral horizontal well \(^{5)\} : \) Interviews with Engineers in services company

### Decision of Land Usage for Horizontal drilling

<table>
<thead>
<tr>
<th></th>
<th>1(^{st}) Year</th>
<th>2(^{nd}) Year</th>
<th>3(^{rd}) Year</th>
<th>4(^{th}) Year</th>
<th>5(^{th}) Year</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Well No.</td>
<td>60 wells</td>
<td>60 wells</td>
<td>60 wells</td>
<td>60 wells</td>
<td>60 wells</td>
<td>300 wells</td>
</tr>
<tr>
<td>Estimated Land</td>
<td>9,000</td>
<td>9,000</td>
<td>9,000</td>
<td>9,000</td>
<td>9,000</td>
<td>45,000</td>
</tr>
<tr>
<td>Required Land</td>
<td>10,000</td>
<td>10,000</td>
<td>10,000</td>
<td>10,000</td>
<td>10,000</td>
<td>50,000</td>
</tr>
</tbody>
</table>

Unit: Acre

---

5) Lopus, Tom. *Quest Eastern Resources*. [Interview]. 2009
Drilling Design

- Casing Design
  - Casing program implemented
  - Setting depths
  - Diameters of strings
  - Production casing design
  - Lateral casing design

- Hydraulic Fracturing Design:
  - 4000 ft lateral
  - Assumptions
  - Stress orientation
  - Number of stages and clusters
  - Pumping rate & pressure
  - Flow back rate
  - Fracture dimensions
  - Proppant size
  - Fluid & proppant amount
Production

From the literature review,

- Production rate varies with shale formation, location, depth and also well type.
- Usually, there is a huge production rate drop in first year, and after 5 year production, the production rate usually drop by 3 ~ 5% of initial production 1).
- Following graph is based on several reports from Range Resources 2), CNS Gas Corp. 3), Cabot Corp. 4), Atlas Energy Resources and Res Energy Corp. 5) which are doing drilling in Marcellus Shale.

Definite Production Rate of a Well

Production Rate of A Horizontal Well (Mmcf/day)

Production from Project

Total Production (Mmcf) vs Year

Year

Total Production


V,
From the literature review,

- The averaging cost of single lateral horizontal well is around 4.0 million dollars \(^1\).
- This cost includes rigs leasing cost, which is around $22,000 per day \(^2\), pad construction, water truck traffic, infrastructure building and local hiring.

### Decision of Drilling Cost

<table>
<thead>
<tr>
<th></th>
<th>1st Year</th>
<th>2nd Year</th>
<th>3rd Year</th>
<th>4th Year</th>
<th>5th Year</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Well No.</td>
<td>60 wells</td>
<td>60 wells</td>
<td>60 wells</td>
<td>60 wells</td>
<td>60 wells</td>
<td>300 wells</td>
</tr>
<tr>
<td>Total Cost</td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>240</td>
<td>1200</td>
</tr>
</tbody>
</table>

Unit: Million Dollar

---

Water Usage

- SRBC Letter to Gas Operators in June, August, October 2008
- Approval for Consumptive Water Use (From public source) by SRBC
  - 20,000 gpd/30-day average (600,000 gallons)
- Approval for Water withdrawals by SRBC
  - 100,000 gpd/30-day average (3,000,000 gallons)
- Certification of proper disposal of flowback
Water removal from Natural Gas

Meet the water content (64 to 110 mg/m³) specifications of the pipeline system

Prevent formation of hydrates in transmission lines

Glycol dehydration unit is the most commonly equipment used in industry to remove water from gas.

Most used liquid desiccant: Triethylene Glycol (TEG) \( \text{HOCH}_2\text{CH}_2\text{OCH}_2\text{CH}_2\text{OCH}_2\text{CH}_2\text{OH} \)

Mechanism:
Gas conditions
T = 100°F
P = 800 psi

Water content: 70 lb/MMcf
Cc = 0.98 * 70 = 68.6 lb/MMcf

Gas composition: 98 % CH₄ and 2 % C₂H₆

MW = 0.98 * 16 + 0.02 * 30 = 16.28 g/mol
SG = 16.28 / 28.96 = 0.56
Location: Franklin Township, Susquehanna, PA
Plant capacity: 100 MMcf/d = 2.83 MMm³/d
**Calculation**

- Gas flow rate = $2.83 \text{MMm}^3/d = 117,917 \text{m}^3/hr$
- Water content = 69lb/MMcf = 1105 mg/m$^3$
- Water limit = 64mg/m$^3$
- Water removal flow rate = $2.83 \times 10^6 \times (1105 - 64) / 1 \times 10^{-6} = 122.7 \text{Kg/hr}$
- TEG Circulation rate = 0.025m$^3$/Kg water removed
- TEG volumetric rate = $122.7 \times 0.025 = 3.07 \text{m}^3/hr$
- Glycol/glycol exchanger
  - $T_1 = 93 \degree \text{C}$, $T_2 = 148 \degree \text{C}$; $Q = 552 \text{MJ/hr}$
- Gas/glycol exchanger
  - $T_1 = 69 \degree \text{C}$, $T_2 = 43 \degree \text{C}$; $Q = -213 \text{ MJ/hr}$
Cost for a TEG plant

Capital cost: 6.5MM$ for a 100 MMcfd glycol dehydration plant
- TEG
- Flash tank
- Operating pressure: 600-800psi

Operating cost and Maintenance
- TEG needed per year: 74950 gallons
- Cost TEG per year: $337,275
- Maintenance: $5000

Total cost = 6.8 MM$
Regulation and Policy on Utilization

FERC judges the application of gas construction

- Clean Air Act
- The natural Gas Act of 1938
- National Environmental Policy act of 1969
- Etc.

The Clean Air Act
Regulation and Policy

Gathering Station and Refinery Facility
NAAQS(National Ambient Air Quality Standards)

<table>
<thead>
<tr>
<th></th>
<th>Primary Standards</th>
<th>Secondary Standards</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Level</td>
<td>Average time</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>9 ppm</td>
<td>8-hour</td>
</tr>
<tr>
<td></td>
<td>35 ppm</td>
<td>1-hour</td>
</tr>
<tr>
<td>Sulfur Dioxide</td>
<td>0.03 ppm</td>
<td>Annual</td>
</tr>
<tr>
<td></td>
<td>0.14 ppm</td>
<td>24-hour</td>
</tr>
<tr>
<td>Nitrogen Dioxide</td>
<td>0.053 ppm</td>
<td>Annual</td>
</tr>
</tbody>
</table>

Penalty: Based on amount of pollutant emission
- CAA, Stationary Source Civil Penalty Policy B.19 Appendix VI
Pipeline Project Overview

Our pipeline project shall be called The Susquehanna Pipeline Project

Major components that will form the Pipeline Project are:
1. Gas transmission pipelines from drilling and production locations to the Gas Treatment Plant
2. A Gas Gathering and Treatment Plant (GGTP),
3. A pipeline from the GGTP to the Columbia Gas Trunk line,
4. 1 Compressor Station

Pipeline Specifications
- 65 miles of 30 inch diameter steel pipeline operating at a pressure of 2,000 psi.
- It will traverse Susquehanna County and be eventually connected at a T-Junction to the Columbia Gas Pipeline.
- 20,000 horsepower compressor station.
- There will be five production stations. Therefore, the GGTP would be located at a point that is equidistant from all five locations
- Capacity to transport approximately 120 million SCF per day of gas with a possibility to expand to 200 million SCF per day of gas
Sequence of Events

- Route Selection
- Survey and Right of Way Acquisition (The width of the right of way varies from about 33ft to 75ft)
- Procurement of materials– Pipe, Valves and Fittings
- Pre-Construction and Construction
- Protection of Pipe
- Pre-Commissioning and Commissioning

Pipe Construction and Protection
Pipe will be externally coated for corrosion protection using external coatings like:
- Coal Tar
- Polyethylene type tapes

Pre-Commissioning and Commissioning
- Before commissioning, pipeline will be subjected to pressure testing according to government regulations.
- The preferable test media is water. However because of winter conditions (as is the case with the Appalachia), it is necessary to use an antifreeze or different fluid such as condensate, sweet gas or air.
- If everything goes well, it is ready to be commissioned and put into use.
The Pipeline Project Workflow

START

Project Design

Route Selection

Obtain Easements

Survey Right of Way

Government Approval

Order Preliminary Pipe and Accessories

Prepare Bid Documents

Receive Bid & Select Contractor

Final Pipe & Accessories

Clear Right of Way

Digging and Pipe Laying

Cover Pipe

Test Pipe

Purge Pipe

Clean-Up Right of Way

Commission and Put into Use

Settle Damage Claims

END

Project Complete & Connected into Columbia Pipeline Grid

Clean-Up Right of Way

Settle Damage Claims
The overall timeline spans three (3) years, from the start of Project Planning to mechanical completion, commissioning and commencement of commercial operations (first gas deliveries).

This is a Success-Case Schedule, i.e., it is based on the assumption that each major activity will be successfully completed in a timely manner.

The key underlying premises to this schedule are that:

- Commercial negotiations with the concerned states – Pennsylvania and New York are successfully concluded and key agreements are executed.
- There are no unanticipated delays in receiving access and key permits/approvals for all components of the project scope.

If issues arise or unanticipated delays occur, the schedule would be extended accordingly.
Pipeline Facility (Regulated by FERC)
NAAQS applied
Compressor Station
- Same as refinery station (Stationary source)
Pipeline Construction
- Diesel emission
Mobile Air Pollution Source
- Hydrocarbon, Particulate Matter, etc.
Penalty: Same as Stationary Source
Sustainable Development

- Reducing the dependence on import of exhaustible fossil fuels.
- Reducing air pollution by sequestering the CO₂ emitted from coal-fired power plants.
- Contributing to local economic development and employment creation.
- Reducing the emissions of greenhouse gases, to combat global climate change.
- Reducing the adverse health impacts.

---

**Import Natural gas (MCF) per year**

- Year 2003: 4,800,000 MCF
- Year 2004: 4,600,000 MCF
- Year 2005: 4,000,000 MCF
- Year 2006: 4,000,000 MCF
- Year 2007: 4,000,000 MCF
- Year 2008: 4,000,000 MCF

**CO₂ per well**

- Year 2003: 4,000 tonnes
- Year 2004: 4,000 tonnes
- Year 2005: 4,000 tonnes
- Year 2006: 4,000 tonnes
- Year 2007: 4,000 tonnes
- Year 2008: 4,000 tonnes

**Revenue Generated**

- Year 2003: $320,000
- Year 2004: $384,000
- Year 2005: $384,000
- Year 2006: $384,000
- Year 2007: $384,000
- Year 2008: $384,000

---

2,000,000 4,000,000 6,000,000 8,000,000 10,000,000 12,000,000 14,000,000
**Contribution to Sustainable Development**

- Reducing the dependence on import of exhaustible fossil fuels.
- Reducing air pollution by sequestering the CO₂ emitted from coal-fired power plants.
- Reducing the adverse health impacts from air pollution.
- Contributing to local economic development and employment creation.
- Reducing the emissions of greenhouse gases, to combat global climate change.

<table>
<thead>
<tr>
<th>No of wells</th>
<th>5</th>
<th>60</th>
<th>60</th>
<th>60</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO₂ per well</td>
<td>4000Tones</td>
<td>4000 tones</td>
<td>4000 tones</td>
<td>4000 tones</td>
<td>4000 tones</td>
</tr>
<tr>
<td>Revenue Generate</td>
<td>$32000</td>
<td>$384000</td>
<td>$384000</td>
<td>$384000</td>
<td>$384000</td>
</tr>
</tbody>
</table>
Economic Evaluation

NPV Analysis
- ROR=15%
- Life=20 yrs

NPV = $790,666,427.01
IRR = 21.24%

Sensitivity Analysis

<table>
<thead>
<tr>
<th>Gas Price *</th>
<th>Drilling Cost</th>
<th>Royalty</th>
<th>Administrative Cost</th>
<th>Lease Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>8.47-10.87</td>
<td>$4.0 million</td>
<td>12.5%</td>
<td>10% + 5% /yr</td>
<td>1500 $/acre</td>
</tr>
<tr>
<td>+40%</td>
<td>306.27%</td>
<td>-58.72%</td>
<td>-32.86%</td>
<td>-4.42%</td>
</tr>
<tr>
<td>+20%</td>
<td>153.14%</td>
<td>-29.36%</td>
<td>-16.43%</td>
<td>-2.21%</td>
</tr>
<tr>
<td>-20%</td>
<td>-153.14%</td>
<td>29.36%</td>
<td>16.43%</td>
<td>2.21%</td>
</tr>
<tr>
<td>-40%</td>
<td>-306.27%</td>
<td>58.72%</td>
<td>32.86%</td>
<td>4.42%</td>
</tr>
</tbody>
</table>

* Source: www.eia.com
**Strengths:**
What advantages do we have? (Prime Location Susquehanna)
What valuable assets and resources do we have? (Sweet gas)

**Weaknesses:**
What could we do better? Technology advancements, Optimization for Cost)
What are we criticized for?
Where are we vulnerable? (Market Volatility, Labor/Lease Cost, assumptions)

**Opportunities:**
What opportunities do we know about, but have not addressed? (Price fluctuation, Petrochemical Industry)
Are there emerging trends on which we can capitalize? (More Production)

**Threats:**
Are weaknesses likely to make us critically vulnerable? (Reliability of data, Propriety data not accessible)
Are economic conditions affecting our financial viability? (Yes)
Conclusion

- Life span of 20 years suggests a viable project.
- NPV comes out to be $790,666,427.01.
- IRR (21.24%) which is well above than ROR (15%).
- Project is highly sensitive to Gas price in market.
- Project contributes to sustainable development.