PENNSTATE

DEPARTMENT OF

ENERGY AND MINERAL ENGINEERING

COLLEGE OF EARTH AND MINERAL SCIENCES

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

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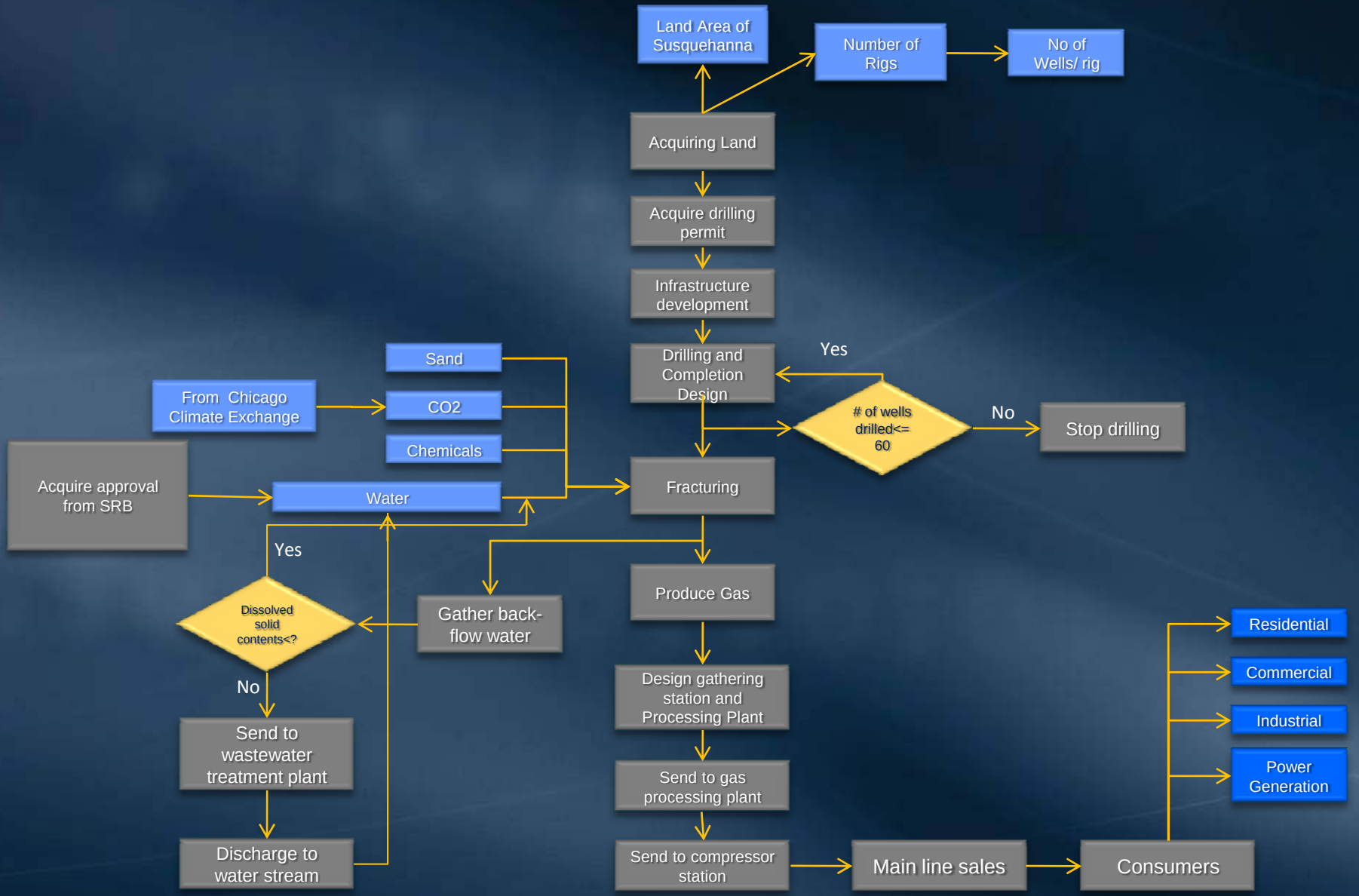
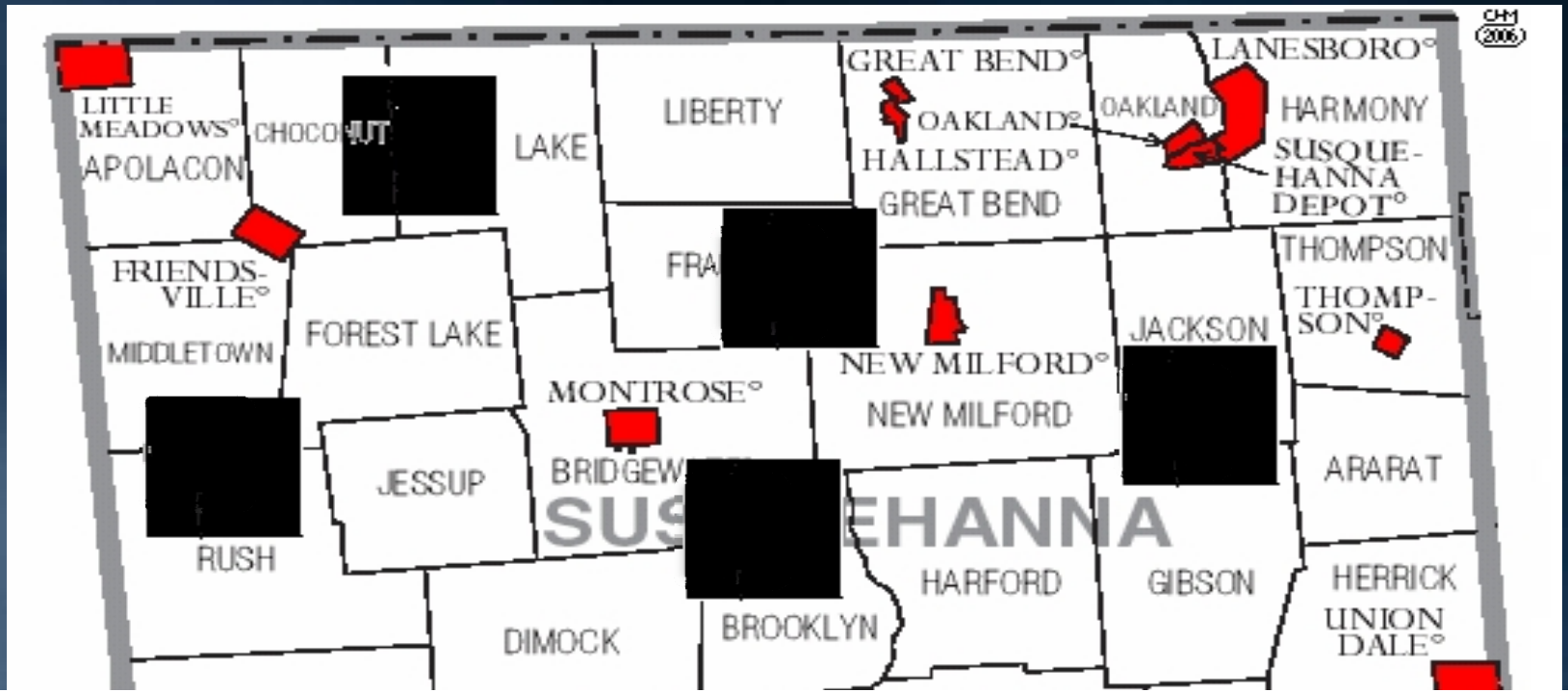
Agenda

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

Design Process Chart



Lease Cost



Year	0	7	14
Lease Cost($/acre)	1500	1500	1500
Land Leased (acre)	50,000	50,000	50,000
Total cost	$75,000,000	$75,000,000	$75,000,000

Land Usage

- 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

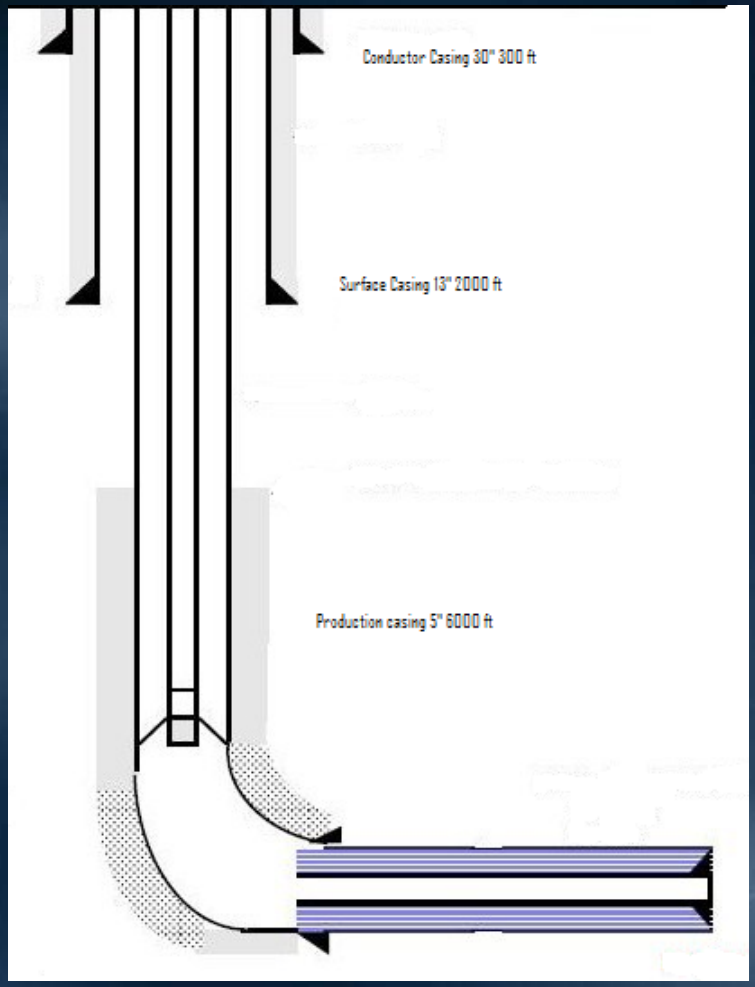
Unit : Acre

	1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
Total Well No.	60 wells	60 wells	60 wells	60 wells	60 wells	300 wells
Estimated Land	9,000	9,000	9,000	9,000	9,000	45,000
Required Land	10,000	10,000	10,000	10,000	10,000	50,000

1) **Sumi, Lisa.** *Shale Gas: Forcus on the Marcellus Shale.* s.l. : For The Oil & Gas Accountability Project/ Earthworks, 2008.
2) **Shuck, L. Zane.** *Public Misinformation about Marcellus Shale.*
3) **Michael, Brownell.** *Gas Well Drilling and Development Marcellus Shale.* New York : Susquehanna River Basin Commission, 2008.
4) **Gill, Brad.** The Facts About Natural Gas Exploration of the Marcellus Shale. [Online] 2008.
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



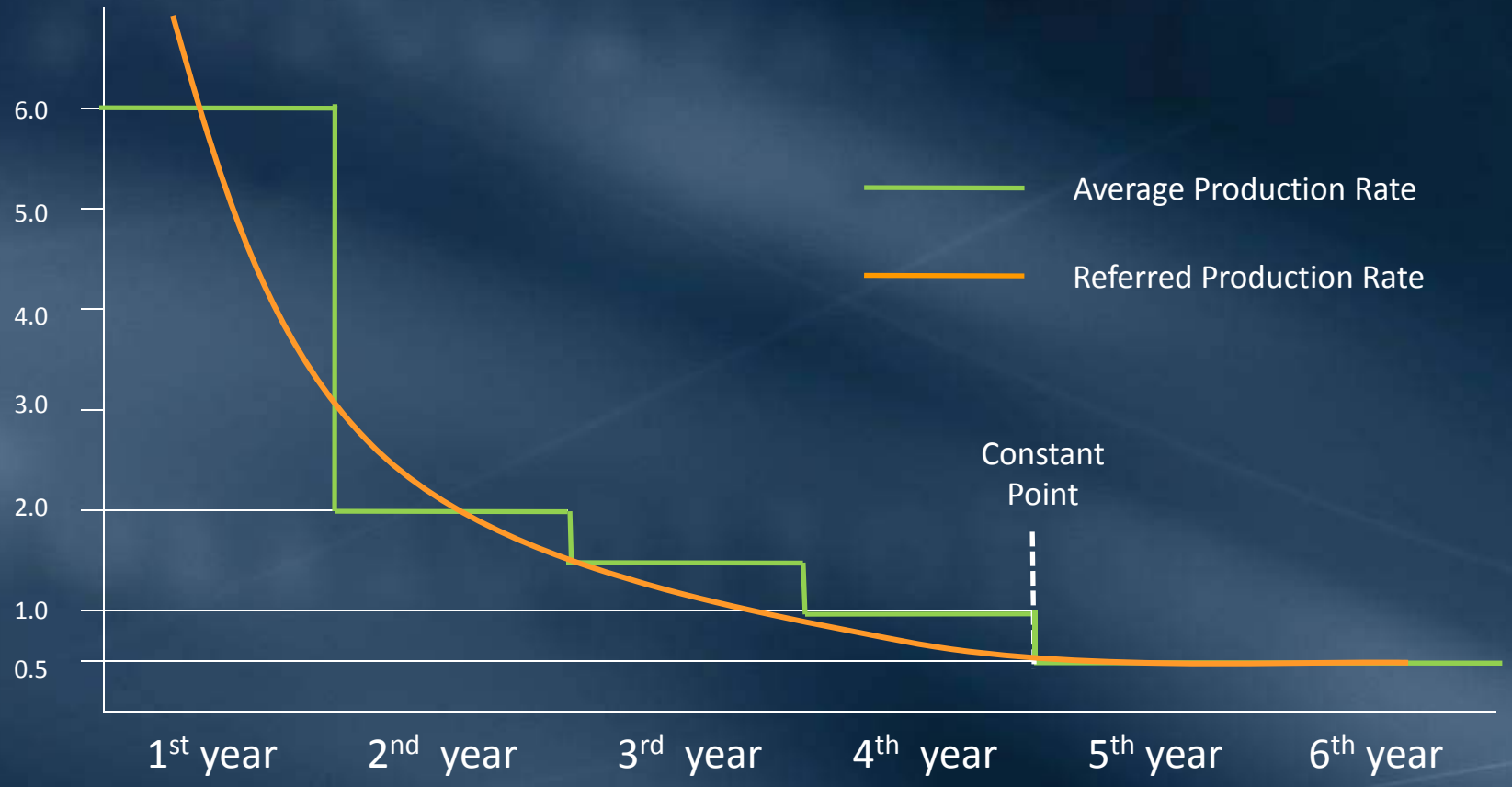
Production

- 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.

1) **ReinHart, John.** *Completion Shale Well (Chesapeake).* Apr. 2th, 2009.
2) Oil Voice. [Online] Range Resources, Jan. 21th, 2009.
3) SCANDINAVIAN OIL GAS MAGAZINE. [Online] CNX Gas Corporation, Dec. 16th, 2008. .
4) Cabot Oil & Gas. [Online] Cabot Oil & Gas Corporation, Dec. 8th, 2008.
5) GlobeNewswire. [Online] Rex Energy Corporation, Dec. 3rd, 2008.

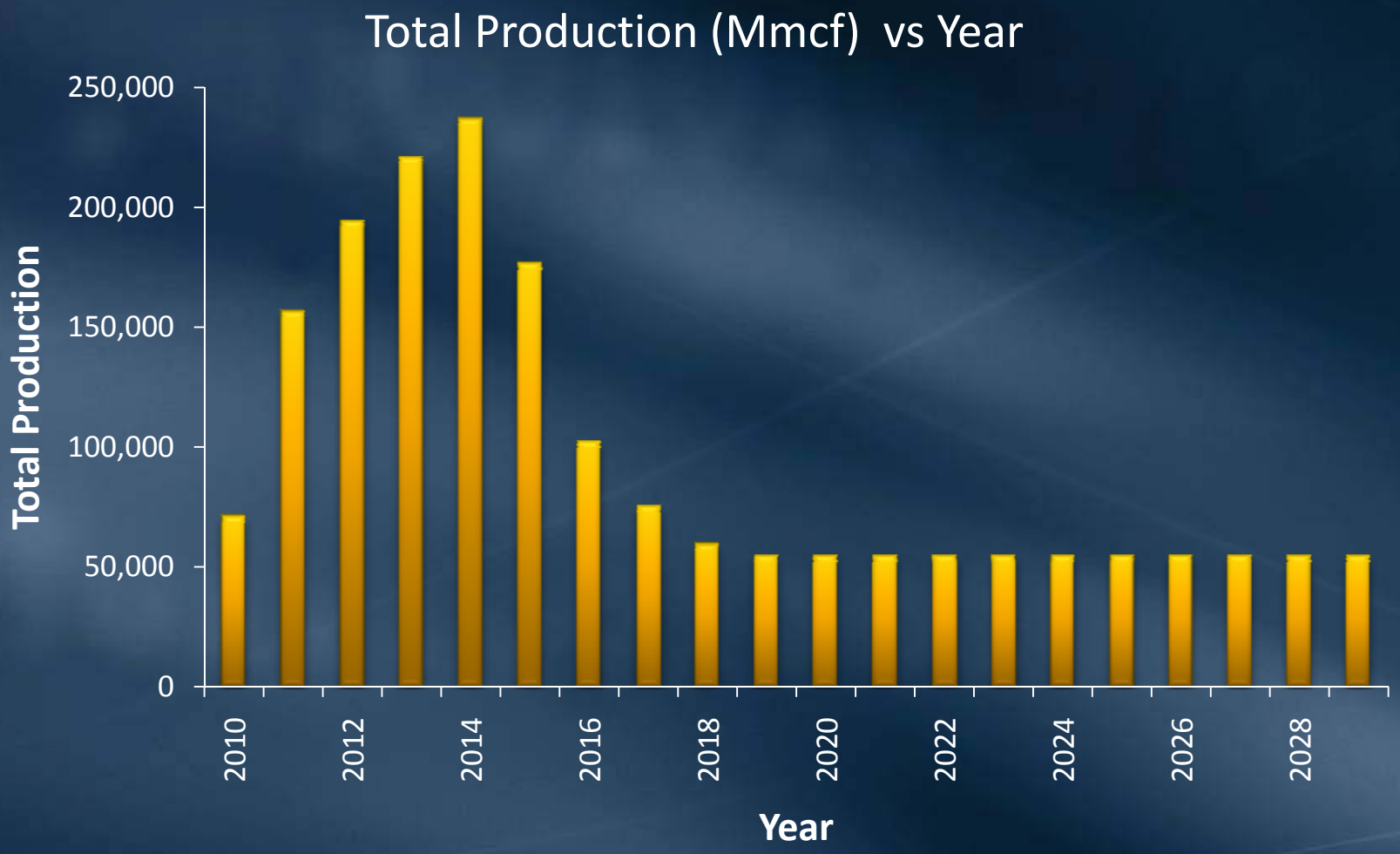
Definite Production Rate of a Well

Production Rate of A Horizontal Well (Mmcf/day)



1) The Friendswille Group. [Online] Mar 16, 2009. http://www.thefriendsvillegroup.org/News_View.aspx?Articleid=123.
2) RLSTORE.COM. *Gas Wells in Susquehanna County Pa.* [Online] Mar 24th, 2009. http://www.rlstore.com/Susquehanna.html.
3) ReinHart, John. *Completion Shale Well (Chesapeake).* Apr. 2th, 2009

Production from Project



Drilling Cost

- 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

Unit : Million Dollar

	1st Year	2nd Year	3rd Year	4th Year	5th Year	Total
Total Well No.	60 wells	60 wells	60 wells	60 wells	60 wells	300 wells
Total Cost	240	240	240	240	240	1200

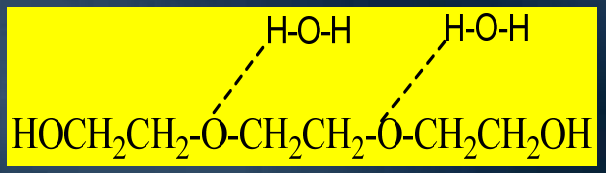
1) **Piquepaile, Roland.** ZDNet. [Online] Jan. 20th, 2008. http://blogs.zdnet.com/emergingtech/?p=809.
2) **ReinHart, John.** *Completion Shale Well (Chesapeake).* Apr. 2th, 2009

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) $HOCH_2CH_2OCH_2CH_2OCH_2CH_2OH$
- Mechanism:



Water content determination

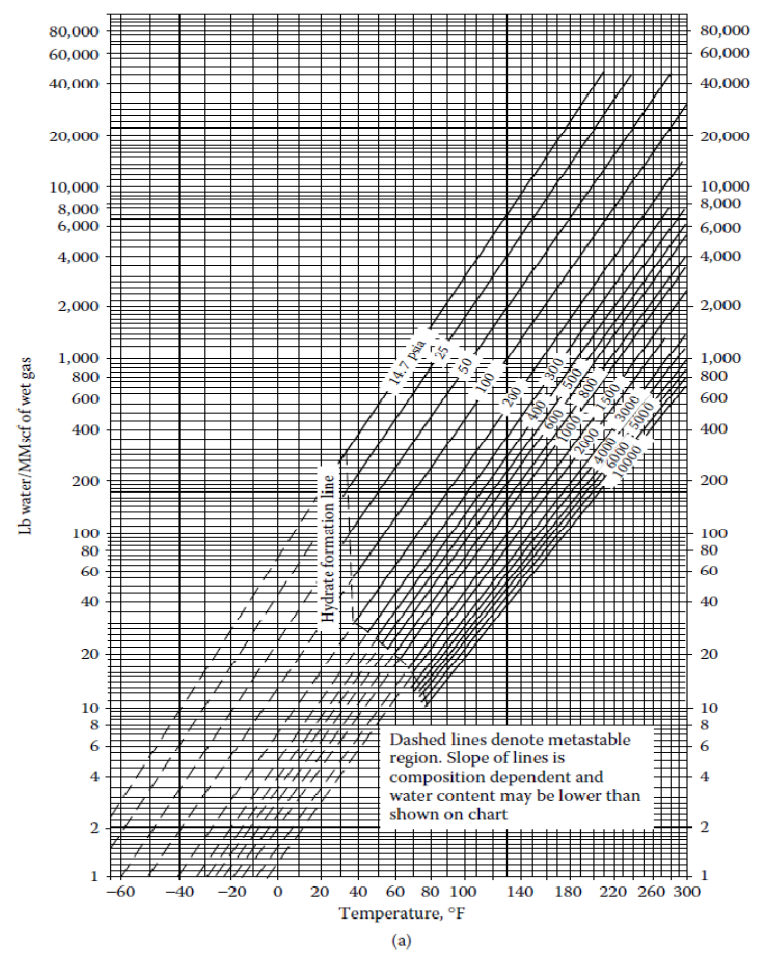


FIGURE 6.1(a) Water content of hydrocarbon gases as a function of temperature and pressure.

Gas conditions

T= 100oF

P=800psi

Water content: 70lb/MMcf

Cc=0.98*70=68.6 lb/MMcf

Gas composition: 98 % CH4 and 2% C2H6

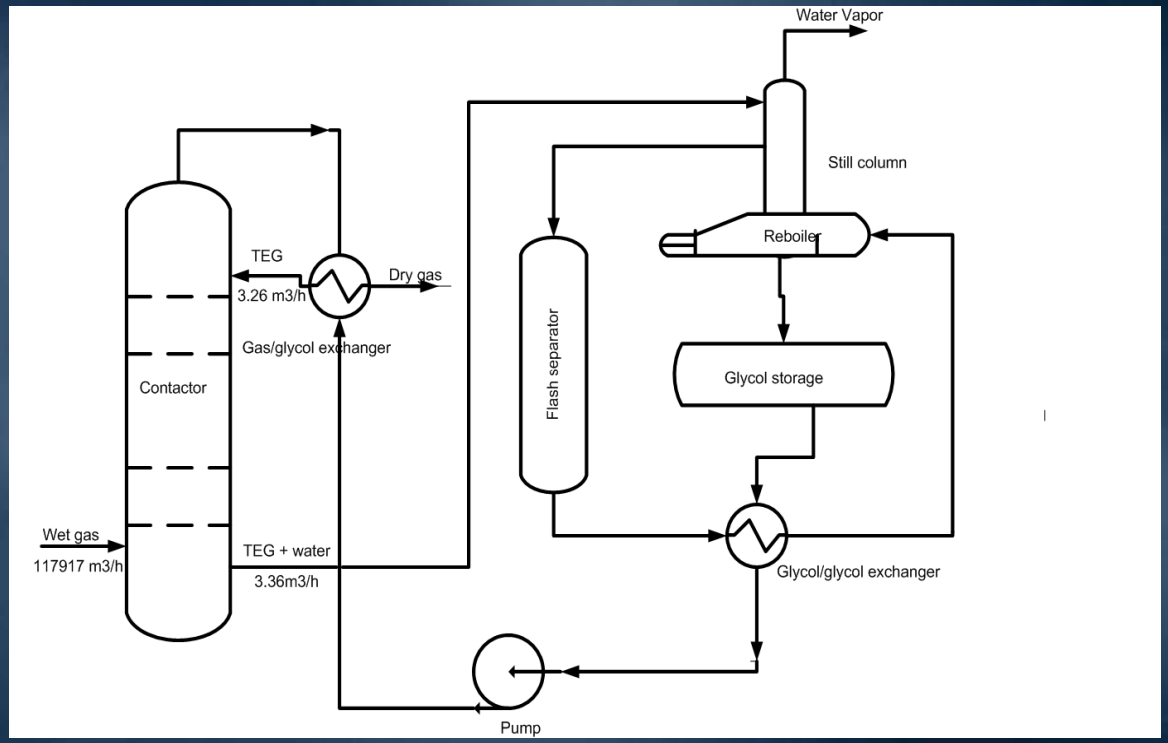
MW=0.98*16+0.02*30=16.28 g/mol

SG= 16.28/28.96=0.56

Kidnay, A and Parrish, W. Fundamentals of Natural Gas Processing, 2006

TEG dehydration plant

Location: Franklin Township, Susquehanna , PA
Plant capacity : 100 MMcf/d=2.83 MMm^3/d



Calculation

- Gas flow rate =2.83MMm^3/d=117,917m^3/hr
- Water content=69lb/MMcf= 1105 mg/m^3
- Water limit 64mg/m^3
- Water removal flow rate =2.83E6*(1105-64)/1E-6=122.7Kg/hr
- TEG Circulation rate= 0.025m^3/ Kg water removed
- TEG volumetric rate= 122.7*0.025=3.07m^3/hr
- Glycol/glycol exchanger
  - T_1=93 ^oC , T_2= 148 ^oC Q=552MJ/hr
- Gas/glycol exchanger
  - T_1=69 ^oC, T_2= 43 ^oC; Q= -213 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

- 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)

	Primary Standards		Secondary Standards	
	Level	Average time	Level	Average time
Carbon Monoxide	9 ppm	8-hour	None	
	35 ppm	1-hour		
Sulfur Dioxide	0.03 ppm	Annual	0.5 ppm	3-hour
	0.14 ppm	24-hour		
Nitrogen Dioxide	0.053 ppm	Annual	Same as Primary	

- 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

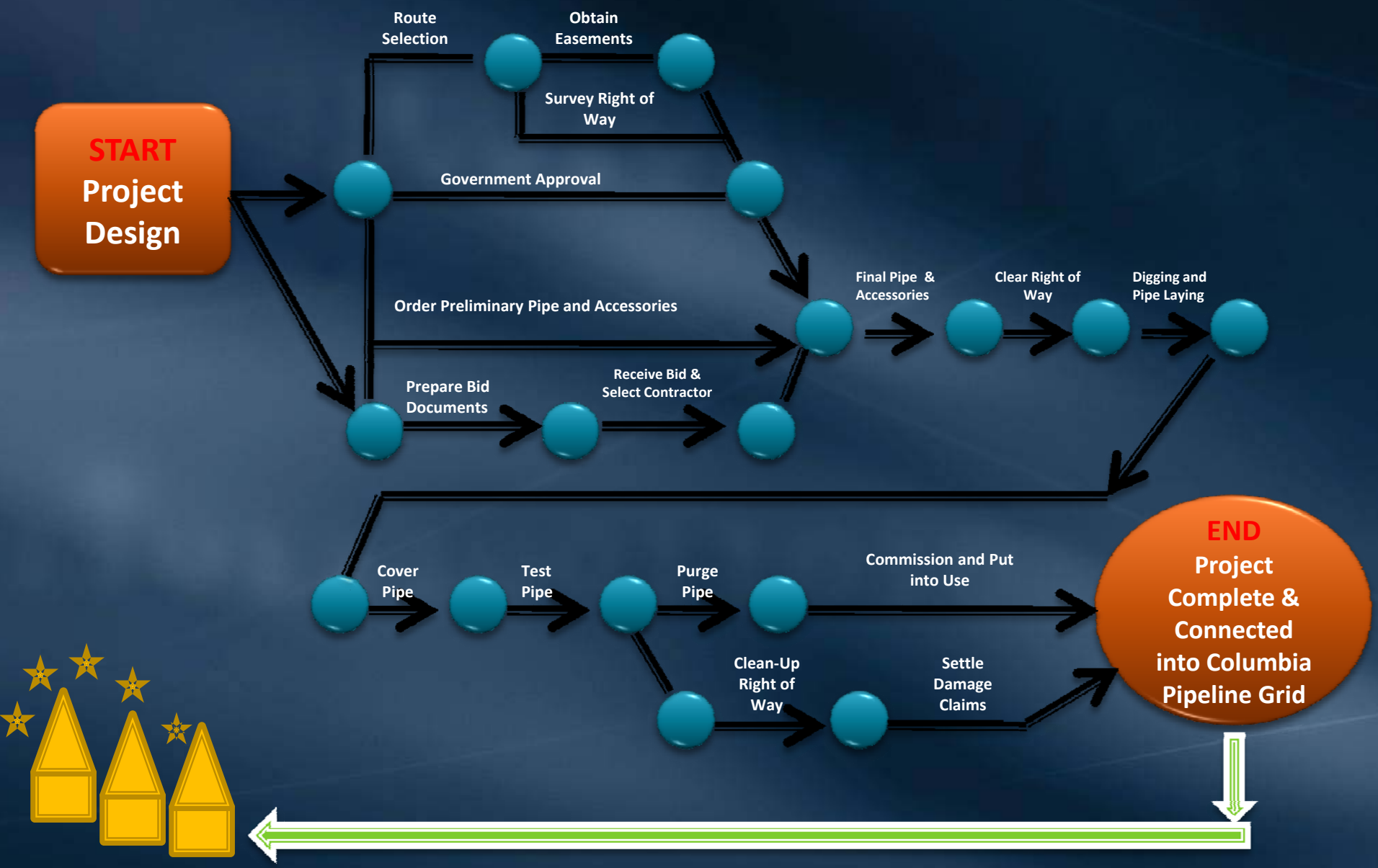
Pipe will be externally coated for corrosion protection using external coatings like:

- 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



Estimated Project Schedule

- 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.

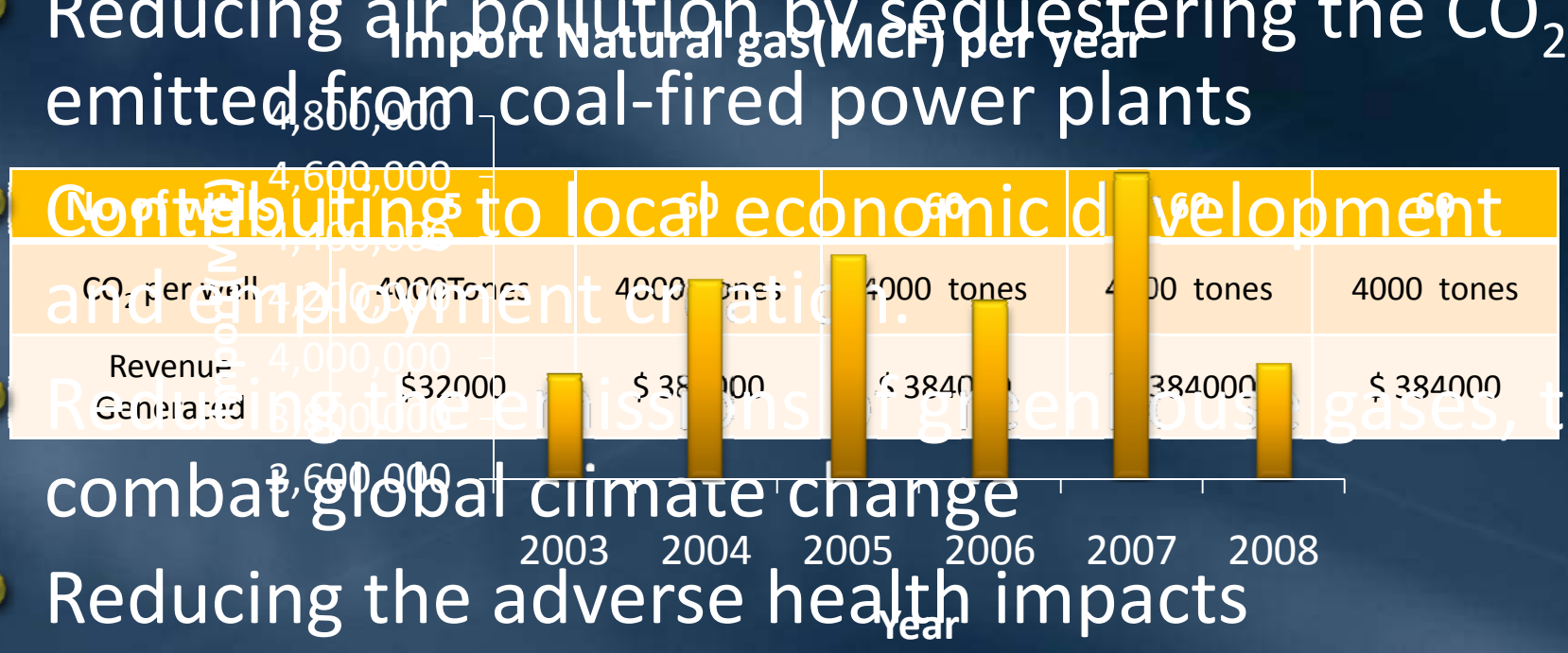
If issues arise or unanticipated delays occur, the schedule would be extended accordingly.

Regulation and Policy

- 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 Developement

- Reducing the dependence on import of exhaustible fossil fuels.
- Reducing air pollution by sequestering the CO_2 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



Contribution to Sustainable Developement

- Reducing the dependence on import of exhaustible fossil fuels.
- Reducing air pollution by sequestering the CO_2 emitted from coal-fired power plants.

No of wells	5	60	60	60	60
CO_2 per well	4000Tones	4000 tones	4000 tones	4000 tones	4000 tones
Revenue Generate	$32000	$ 384000	$ 384000	$ 384000	$ 384000

- 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

Economic Evaluation

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

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

- Sensitivity Analysis

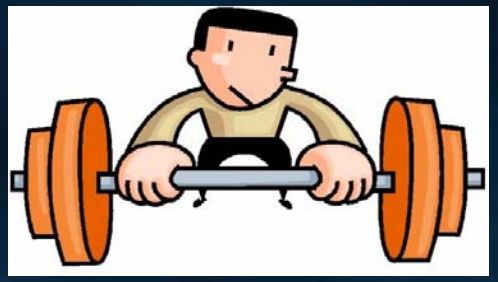
	Gas Price *	Drilling Cost	Royalty	Administrative Cost	Lease Cost
	8.47-10.87	$4.0 million	12.5%	10% + 5% /yr	1500 $/acre
+40%	306.27%	-58.72%	-50.42%	-32.86%	-4.42%
+20%	153.14%	-29.36%	-25.21%	-16.43%	-2.21%
-20%	-153.14%	29.36%	25.21%	16.43%	2.21%
-40%	-306.27%	58.72%	50.42%	32.86%	4.42%

* Source: www.eia.com

SWOT

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.