Cooperative Agreement in support of
the “Smart Development Initiative”

MONTHLY REPORT – FEBRUARY 2006

Prepared for:
Energy Division—Energy Sector Governance Program
Office of Infrastructure & Engineering
Bureau for Economic Growth, Agriculture and Trade
U.S. Agency for International Development

Prepared by:
Center for Energy Economics
Bureau of Economic Geology
University of Texas, Austin

March 3, 2006
USAID Cooperative Agreement
Monthly Report
February 2006

The following are the activities conducted in the month of February. They mostly fall under Task 1 – Continuation of Work in Ghana except for work on redesigning the New Era program schedule partly to better incorporate Smart Development concepts (Task 4).

- Mr. Essandoh-Yeddu, Director of Strategic Planning and Policy Division at EC, arrived in Houston on February 6. He will stay in Texas until August 2006. Immediately, Mr. Essandoh-Yeddu started working on CO2 modeling project with Dr. Sue Hovorka, Dr. Ian Duncan and Ms. Vanessa Nunez-Lopez. Dr. Gülen provides assistance as needed.

- On February 15, CEE conducted a one-day “Natural Gas Workshop” in Washington D.C. for the Ghanaian delegation in town for the NARUC winter meeting. Dr. Gülen, assisted by Ms. Miranda Wainberg, conducted the workshop. In addition, Mr. Mark Lewis from Baker Botts LLP provided a presentation addressing questions raised by the Ghanaian delegation regarding the development of a secondary natural gas market. Verbal feedback from the participants indicates that the delegates found the workshop useful and a good medium for discussing their options. Workshop agenda and presentations are provided in Attachment 1.

- CEE invited Michel Layec, Lead Energy Economist for the World Bank responsible for the West African energy issues, to the workshop. Mr. Layec was involved in the WAGP project and is now leading the Bank’s effort in WAGP countries to develop natural gas markets and human capacity to manage these markets. Mr. Layec discussed Bank’s plans for further natural gas work in West Africa with some of the delegates and Dr. Gülen. CEE is continuing the dialogue with Mr. Layec for coordinating future work in the region.

- From February 18 through March 3, CEE hosted Mr. Emmanuel Quaye-Foli from the Ministry of Energy and Mr. Seth Adjei-Boye from PURC. They were in the U.S. for the NARUC exchange program. CEE and NARUC, with the support of the Mission, worked together and were able to extend their visit. They were joined by Mr. Essandoh-Yeddu from EC. The goal of the visit was to provide further exposure to natural gas business in one of the oldest yet still growing markets in the world, Texas, and allow representatives of three key agencies in Ghana to work together on the LDC economics. The final agenda for the two-week visit, the presentation on the natural gas business and participant evaluation forms are provided in Attachment 2. As the evaluations indicate, the participants found these two weeks in Texas exceptionally valuable. Some highlights from the visit include the following.
  - The trio had an opportunity to visit regulatory agencies, two LDC’s (CPS Energy of San Antonio, a large municipally owned utility and Grey Forest Utilities, a small, almost all residential utility, also municipally owned), LNG and CNG businesses in Texas and to work on an economic model for the LDC in Tema.
  - The visit was also serendipitous in that they interacted with Dr. Ben Asante, a Ghanaian pipeline engineer with worldwide experience and keen interest to assist them. Dr. Asante is the Principal Consultant for Pipeline Design Solutions, Ltd. Dr. Asante has been in touch with the Ministry in Ghana but having access to him for two weeks while in Houston was greatly appreciated by our visitors. Dr. Asante’s input was particularly helpful with sizing and costing the pipeline network for the Tema region.
Working on the model, the visitors were convinced of the absolute necessity of having better information on natural gas demand potential in Tema and on the level of interest or better yet the level of commitment among potential users. As such, they will try to work with Dr. Felix Asante of RCEER to secure timely implementation of the RCEER surveys and a high rate of response.

As a result of his exposure to various entities in Texas, Mr. Quaye-Foli also suggested two more exchange programs: 1- an internship program for a Ghanaian team from the Ministry, PURC and EC at the Grey Forest Utilities, a small but growing LDC in northwest San Antonio, to learn about the business, operation and regulation (including safety) of such a network (Grey Forest extended an open invitation for such a program); 2- an internship program at the Bureau of Economic Geology (CEE’s home at UT-Austin) for geologists and petroleum engineers from the Ghana National Petroleum Corporation (GNPC) to learn about most recent advances in these fields and to analyze Ghanaian geological data together with BEG’s and industry experts. Mr. Quaye-Foli is pursuing options for funding these internships.

The group visited with Mr. Al Boulos and Mr. Terence Barr. Mr. Al Boulos, a highly respected international petroleum negotiator with decades of experience worldwide and in West Africa in particular, was appointed advisor to the Minister in Ghana several years ago. He now works with Mr. Barr and his company Afex International, which has offshore upstream interests in Ghana. The meeting exposed issues associated with developing domestic natural gas potential in Ghana and reconciling this potential with the WAGP volumes.

Dr. Foss, Dr. Gülen and Dr. Gurfinkel attended the Energy Week organized by the World Bank, where they had a chance to interact with Dr. Harriette Amissah-Arthur, Director of Kumasi Institute of Technology and Environment and Mr. Jabesh Amissah-Arthur, consultant (ex-VRA). KITE has been an early supporter of RCEER. They are both good candidates for further involvement with RCEER. Dr. Foss and Dr. Gülen also had a chance to visit with Prof. Adegbulugbe, Special Adviser to the President on Energy in Nigeria and his colleague Dr. Adenikinju. They were interested in supporting our activities in Nigeria. The CEE team also met with Mr. Layec to further discuss possibilities for joint work and coordination in West Africa around the WAGP and associated gas market developments.

Dr. Gülen and Dr. Foss edited the Natural Gas Primer and sent it to Dr. Asante for getting it ready for publication.

CEE continued to work on further incorporation of Smart Development concepts into the New Era program.

Next steps

- Subcontract to be finalized by UT OSP; once finalized:
  - RCEER to publish its information flyer
  - RCEER to implement the public survey on natural gas
  - RCEER to publish Natural Gas Primer in book form
ATTACHMENT 1

Workshop on Natural Gas Industry
for the Ghanaian Delegation
by the Center for Energy Economics,
Bureau of Economic Geology
University of Texas at Austin
in collaboration with NARUC
February 15
NARUC Winter Meetings
Washington D.C.

Agenda

9:00-10:30
Overview of physical infrastructure
- Gathering & processing
- Transportation via larger diameter long-distance pipelines through high pressure compression
  - Metering
  - Supervisory Control and Data Acquisition (SCADA)
- Local distribution via smaller diameter pipeline network through low pressure compression
  - Metering
- Storage
  - Underground geological
  - Liquefied natural gas

10:45-12:00
Natural Gas Value Chain Investment Considerations
- Uses & customers
- Regulated infrastructure
- Pipeline cost structures
- Case studies

12:00-14:00
Lunch

14:00-17:00
Considerations for Ghana
- Building the pipeline infrastructure
  - Transmission versus distribution
  - Public versus private investment / ownership
  - Cost recovery (tariffs)
  - Awarding distribution franchises
- Competitiveness of natural gas
  - Industrial uses
  - Power generation
- Opportunities for new uses of natural gas
- Transportation sector
  - Natural gas markets
    - Bundled and unbundled services
    - Spot, forward and futures markets
  - International pipelines
    - Agreements & disputes
    - Security & diversification
What is Natural Gas?

- A combustible, gaseous mixture of simple hydrocarbon compounds, mostly methane.

Source: www.naturalgas.org

Where is it Used?

- Residential uses: cooking, water heating, space heating and/or cooling.
- Commercial uses: space heating, water heating, and cooling.
- Transportation uses: CNG, LNG as fuel (~2.5 million vehicles worldwide)
- Power generation: Steam, simple cycle, combined cycle, micro turbines, fuel cells

Where is it Used?

- Industrial uses:
  - base ingredients for such varied products as plastic, fertilizer, anti-freeze, pharmaceuticals and fabrics
  - pulp and paper, metals, chemicals, petroleum refining, stone, clay and glass, plastic, and food processing
  - waste treatment and incineration, metals preheating (particularly for iron and steel), drying and dehumidification, glass melting, food processing, and fueling industrial boilers

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Gathering
* Removal of basic sediment & water
* Collection through field and gathering lines for removal of free liquids and extraneous materials
* Gas may also be sweetened with chemical agents to neutralize sulfur compounds and carbon dioxide
* From 2 inches to 24 inches in diameter
* Higher pressures than transmission lines—up to 2160 psi (≈150 bar)
* Generally, feed gas processing facilities

Processing
* Liquefy the heavier molecules that occur in the gas stream in order
  * to make the gas production marketable and safe for pipelines, and
  * to increase profits from the lease (non-methane molecules are marketable)
* "Wet" gas contains a higher proportion of larger molecules as well as oil condensate as opposed to "dry" gas.

Natural Gas Products

Pipeline Transportation
* Line pipe—high strength carbon steel—seamless or welded (>24-inch)
* Strict metallurgical standards dictated by API
* Pipe joints are welded together
* Pipe Coating—Fusion Bond Epoxies (FBE)—Used to prevent external corrosion

Compressor Stations
* The compressor or pumping station is the "engine" that boosts pressure and moves gas (1,300 psi ≈ 90 bar)
* Typically installed every 40 to 100 miles—depending on number of compressors & HP, and diameter of pipe and volume to be moved
* Stations also typically have liquid separators in the form of scrubbers, strainers or filter separators.

Metering & Regulation
* Metering Stations are the "cash register" of the industry
  -- Orifice meters
  -- Turbine meters
  -- Ultrasonic meters
  -- Positive displacement meters
* Regulation serves to reduce pipeline pressure to an acceptable level for distribution and end use

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Value Chain
**Operations**

- Mainline valves spaced 5 to 20 miles apart depending on population density and safety codes
- Allow isolation of pipeline segments for maintenance and emergencies

**Operations**

- Supervisory Control and Data Acquisition (SCADA) is a communication system to monitor and control certain equipment on the pipeline
- Transmits operating status, flow volumes, pressure and temperature data from compressor stations, M&R facilities and valves to a gas control facility
- Facilitates nominations, scheduling procedures, allocations & billing

**Operations**

- Integrity Assurance
  - Aerial Patrols
  - Pipeline Markers
  - Damage Prevention Program
  - Cathodic Protection
  - Pipeline Pigging
  - Leak Detection Surveys

**Distribution**

- From citygate to customers
- Small-diameter pipe (<12-inch)
  - Traditionally steel, but increasingly polyethylene (PE)
- 3 psi of pressurization
- Mercaptan (NG is odorless)
- Metering & billing
- ~50% of end-user price (U.S.)

**Storage**

- Gas storage supplements pipeline deliverability in peak demand winter periods
- Generally, storage fields are depleted reservoirs, aquifers or salt caverns
- In distribution regions, there are smaller LNG storage facilities used for "peak shaving"

**Depleted reservoirs**

- 50% base gas
- Advantages:
  - Typically near existing regional pipeline infrastructure.
  - Already a number of useable wells and field gathering facilities.
  - Low risk of reservoir "leaks".
- Disadvantages:
  - Working gas volumes are usually cycled only once per season.
  - Substantial amount of well maintenance & monitoring to limit wellbore leaks.
Aquifer

- Advantages:
  - Typically, close to end user market.
  - High deliverability high quality reservoirs + water drive.
  - The ability to cycle the working gas volumes more than once per season.

- Disadvantages include:
  - A high level of geological risk - risk for substantial reservoir leaks.
  - Water production is often experienced during the withdrawal cycle, increasing operating costs.
  - Due to the water drive mechanism, the base gas requirements are high (80%). A large percentage of base gas is not recoverable after site abandonment. (increases the initial capital cost).

Salt cavern

- Advantages:
  - Low base gas requirements of 25% or less.
  - Ultra-high deliverability.
  - Operational flexibility - can cycle working gas 4-5 times a year.
  - Salt caverns provide excellent seals - risk of reservoir gas leaks is small.

- Disadvantages:
  - Costly initial startup (disposal of the saturated salt water generated during the solution mining process can be costly and environmentally problematic).

Typical Firm Storage Costs

<table>
<thead>
<tr>
<th>Fee</th>
<th>Salt Dome Storage</th>
<th>Reservoir Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fuel Fees (based on MMBCF of capacity retained)</td>
<td>$1.00</td>
<td>$1.40</td>
</tr>
<tr>
<td>Annual Demand Charge (MMBCF)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Variable Costs (based on volume of footage)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inflation Fee, $/MMBtu</td>
<td>$0.02</td>
<td>$0.02</td>
</tr>
<tr>
<td>Withdrawal Fee, $/MMBtu</td>
<td>$0.02</td>
<td>$0.02</td>
</tr>
<tr>
<td>End Expensive, %</td>
<td>1.00</td>
<td>1.00</td>
</tr>
<tr>
<td>Inflation Days To Fit</td>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>Withdrawal Days To Deplete</td>
<td>10</td>
<td>120</td>
</tr>
<tr>
<td>Total Number Of Cycles Per Year</td>
<td>4 to 5</td>
<td></td>
</tr>
</tbody>
</table>

The U.S. Natural Gas Industry

U.S. Pipelines

- ~22,000 miles of gathering lines
- 237,079 miles of gas pipelines
  - 194,673 miles of long distance transmission lines,
  - 37,339 miles of field lines and
  - 5,067 miles of storage lines.
- Over 1 million miles of distribution pipelines.
- 152,005 miles of liquids pipelines.

Natural Gas Value Chain

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Worldwide Natural Gas System Dynamics: Framework/Investment Issues, Role of Grids

- **E&P (LNG)**: Profit driven; ROR decision based on expected prices; monetize stranded reserves.
- **Power Gen**: Profit driven; ROR decision based on expected prices; fuel competition for gas.
- **Pipelines**:
  - Regulated asset optimization; market.
- **Transmission**: Cost.
- **LDCs**:
  - Regulated asset; optimization; proximity to end customers; gas; power; model.
- **End Users**: End use based on expected prices; access to competitive supply.

Cheapest fuel for power generation

Cheapest fuel for power generation

Cleaest Fossil Fuel

Fossil Fuel Emission Levels
- Pounds per Billion Btu of Energy Input

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Natural Gas</th>
<th>Oil</th>
<th>Coal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Dioxide</td>
<td>117,000</td>
<td>104,000</td>
<td>208,000</td>
</tr>
<tr>
<td>Carbon Monoxide</td>
<td>40</td>
<td>33</td>
<td>208</td>
</tr>
<tr>
<td>Nitrogen Oxides</td>
<td>92</td>
<td>448</td>
<td>457</td>
</tr>
<tr>
<td>Sulfur Dioxide</td>
<td>1</td>
<td>1,122</td>
<td>2,591</td>
</tr>
<tr>
<td>Particulates</td>
<td>7</td>
<td>84</td>
<td>2,744</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.000</td>
<td>0.007</td>
<td>0.016</td>
</tr>
</tbody>
</table>

Source: EIA - Natural Gas Emission Trends 2000

Return on Energy Investment 1993-2002

- Stand gas systems
- Electricity
- Gas downstream


Global Gas Investment


<table>
<thead>
<tr>
<th>Year</th>
<th>Gas Pipelines</th>
<th>Exploration &amp; Development</th>
<th>Transmission</th>
<th>Gas Storage</th>
</tr>
</thead>
<tbody>
<tr>
<td>2001-2010</td>
<td>90</td>
<td>60</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>2011-2020</td>
<td>120</td>
<td>90</td>
<td>60</td>
<td>60</td>
</tr>
<tr>
<td>2021-2030</td>
<td>150</td>
<td>120</td>
<td>90</td>
<td>90</td>
</tr>
</tbody>
</table>


Gas Pipeline Additions


Value Chain

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Typical Gas Pipeline Construction Costs, Onshore vs. Offshore

<table>
<thead>
<tr>
<th>Country</th>
<th>Diameter (inches)</th>
<th>Total Length (km)</th>
<th>Unit Cost (US$/inch/km)</th>
</tr>
</thead>
<tbody>
<tr>
<td>United States</td>
<td>24</td>
<td>463,000</td>
<td>26</td>
</tr>
<tr>
<td>Korea</td>
<td>28</td>
<td>2,066</td>
<td>21</td>
</tr>
<tr>
<td>Russia</td>
<td>36</td>
<td>150,000</td>
<td>14</td>
</tr>
<tr>
<td>Ukraine</td>
<td>32</td>
<td>36,700</td>
<td>16</td>
</tr>
<tr>
<td>Brazil</td>
<td>23</td>
<td>7,700</td>
<td>20</td>
</tr>
<tr>
<td>Argentina</td>
<td>30</td>
<td>12,800</td>
<td>21</td>
</tr>
</tbody>
</table>


Comparative Gas Pipeline Costs by Size (Diameter)

Example: African Pipelines

<table>
<thead>
<tr>
<th>Pipeline</th>
<th>Origin Destination</th>
<th>Capacity (bbl/d)</th>
<th>Length (km)</th>
<th>Year of Operation</th>
<th>Cost (Billion $)</th>
</tr>
</thead>
<tbody>
<tr>
<td>GME</td>
<td>Algeria - Spain (via Morocco)</td>
<td>200</td>
<td>1,620</td>
<td>2004</td>
<td>0.2</td>
</tr>
<tr>
<td>Medgaz</td>
<td>Algeria - Spain</td>
<td>110</td>
<td>1,470</td>
<td>2004</td>
<td>2.0</td>
</tr>
<tr>
<td>Gaslink</td>
<td>Algeria - Italy</td>
<td>8</td>
<td>248</td>
<td>2004</td>
<td>0.2</td>
</tr>
<tr>
<td>Arab Mashreq</td>
<td>Egypt - Jordan</td>
<td>3</td>
<td>1,540</td>
<td>2005</td>
<td>1.0</td>
</tr>
<tr>
<td>Green Stream</td>
<td>Libya-Tunisia</td>
<td>3</td>
<td>990</td>
<td>2005</td>
<td>0.6</td>
</tr>
<tr>
<td>Traco-Sahelren</td>
<td>Nigeria - Libya</td>
<td>10</td>
<td>4,000</td>
<td>After 2010</td>
<td>7.0</td>
</tr>
</tbody>
</table>

Example Pipeline Financing: Africa

Regulated Infrastructure as the Conduit for Supply

The challenges:
- Rate-making style
- Pricing new capacity
- Dealing with access for new capacity
- Dealing with market power
- Balancing short term cycles and long term capital requirements
Where applicable:
- Setting maximum allowable rates with market transparency
- Determining contestability of transportation markets

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Value Chain
U.S. - Rate of Return, or Cost of Service

**ROR or COS:**
- Bottom-up approach to pricing
  - The goal is to disaggregate the costs (unbundled)
  - To avoid arbitrary cost allocations
- Considerations
  - Costly regulation to implement
  - Possibilities of "gold plating"
  - Needs to be complemented with benchmarking
  - Not clear efficiency in income distributional concerns
  - It can lead to discriminatory service obligations

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Cost of Service Ratemaking Model

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Outside of U.S.: Price Cap

Price cap regulation (CPI-X +/- Z)
- Maximum tariff + adjustments
  - In practice it resembles ROR/COS regulation when it includes net present value of future capital outlays
- The cap is on the adjustments; the price rises with inflation measured by CPI minus a productivity growth adjustment (X) +/- adjustments (Z) for unique developments (e.g. environmental or tax laws)
- Often preferred by governments because it may be easier to implement

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Price Cap Yardstick

- **Benchmarking/yardstick** - Compensation based on performance of "comparable" firms
  - Provides incentives to cut costs
  - Dampens the effects of information asymmetries
  - Requires resources to develop appropriate yardsticks
  - May not be possible in some situations.
  - Statistical benchmarking can reduce information asymmetries; regulatory agencies can share information
  - The best comparisons are on some overall dimension
  - Publication of overall performance comparisons can put pressure on poorly performing firms

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Awarding LDC franchises – Turkish case study

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### General Requirements
- Qualified companies submit bids on distribution tariff
- 3 lowest offer further discounts
- Lowest distribution tariff wins bid (fixed for the first 8 years)
- Must start construction in 6 months
- Must start gas delivery in 18 months
- Must connect everyone in 5 years
- 30-year franchise

### Prequalification of Bidders
- Financial viability - equity, balance sheets and income statements and documents and letters of intent showing how the investment shall be financed
- Experience of the bidder or the firms which will provide design, construction and operation services to the bidder, in the natural gas sector and other sectors.

### Case Study – City of Erzurum
- ~375,000 residents
- Average January temperature -11°C
- 81 active industrial plants
  - mostly small to medium enterprises
  - 40 non-operational
- New industrial park
- Mining opportunities
- $1.2 billion of GDP

### Awarding LDC Franchises – Northern Ireland Case Study

### Case Study – City of Erzurum
- Investment
  - $4.8 million in 2004 for 122 km of pipe + other facilities
  - 2005-33: $11.2 million for 261 km of pipe + other facilities
- 40,000 residential customers by 2005, consuming 86 MMcm/year
- 42 MMcm/year C&I load
- 6.4 bcm cumulative 2004-2033

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General Characteristics

- Drivers
  - Environmental reasons
  - Desire to attract investors
  - Conversion of a power plant to NG
- 600,000 households
- 250,000 in greater Belfast
- Small C&I market
- Combined license for distribution & supply

Monopoly in transportation

- Exclusive distribution license for 20 years
  - to attract investors
  - to mitigate market, financial and technical risks
  - to optimize network construction
  - to simplify regulation & supervision

Development obligations

- Licensed LDC
  - to complete network in 12 years
  - to perform in each district in a specific order and within a specific timeframe
  - to install a pipe within 50 m of 90% of the homes in each district (challenged by the LDC)
- Challenges: monitoring & penalties

Distribution tariff

- Consumer rate = NG supply charge + distribution tariff
- Standard approaches are not appropriate
  - asset base starts from zero ➔ high tariffs early on, BUT
  - need low rates to persuade consumers to switch to NG early on

Distribution tariff

- Expected 8.5% real pretax return on cash flows over 20 years
- Problem: uncertainty of forecasts
  - capital and O&M costs
  - sale levels
  - mixture of residential and C&I users
- Solution: reforecast every 5 years

Distribution tariff

- LDC will retain any gains or bear any losses based on revised forecast ➔ incentive for market development
- Prices to be adjusted such that NPV stays the same as the original NPV
- Controversy: allocation of costs across different consumer segments
Competition in supply

- Avoided in a new market
- There are benefits to having an integrated network development approach
- It is difficult for regulators & LDC to allocate costs to transport & supply
- LDC got 4-5 years of monopoly supply status for small users and 2-3 years for larger users

Prices to final users

- No regulation for the first 5 years
- Counting on competition between fuels (NG v LPG v heating oil)
- After 5 years, regulator may decide on a price formula for small users (<7 million cubic feet a year)

Today

- LDC signed up 93,000 customers since 1996
- Growing at 20% a year
- Invested almost $500 million in infrastructure (~3,000 km of pipe)
- Not expected to go cash positive until 2006 – 10 years after the investment started

Awarding LDC franchises – Mexico case study

based on
Describing Natural Gas Distribution Concessions in a Megacity: Tradeoffs between Scale Economies and Information Disclosure in Mexico City by Joan Roselló & Jonathan Hultman, World Bank, Latin America and the Caribbean Region, Finance, Private Sector, and Infrastructure Sector Unit

General characteristics

- Bid-based concessions
  - winner is the lowest average revenue for the first five-year period
  - minimum coverage: 350,000 for Federal District and 300,000 in State of Mexico consumers at the end of 5 years
  - $1 billion in investment commitments

General characteristics

- 12 years exclusivity for distribution but not for marketing
  - average revenue yield price caps for distribution tariff
  - marketing price is not regulated unless there is no competition → acquisition price methodology
Winning Bids

- coverage commitments of almost 440,000 consumers in the Federal District and 370,000 in the State of Mexico after 5 years, and
- $0.5 billion in investment after 10 years.
- Average revenue cap is $0.6/MMBtu in FD > $0.38/MMBtu national avg

Natural gas in Bangladesh

Bangladesh Energy Sector

Petrobangla

Exploration & Production
Transmission
Marketing
CNG/LPG
Mining

Pipeline Network

1,800 km high pressure transmission line of 8 inch to 30 inch diameter operating at 900 psig, supported by ~1,500 km of intermediate pressure pipelines and ~11,000 km of service pipelines

Marketing and Consumption

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### Gas Demand Forecast

**March, 2004**

<table>
<thead>
<tr>
<th>Year</th>
<th>AVG</th>
<th>MAX</th>
<th>AVG</th>
<th>MAX</th>
<th>AVG</th>
<th>MAX</th>
<th>AVG</th>
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<td>2003-04</td>
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<td>2004-05</td>
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<td>2005-06</td>
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### Gas Tariff

<table>
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<th>Year</th>
<th>Power</th>
<th>Rent</th>
<th>Input</th>
<th>Tariff</th>
<th>Gas</th>
<th>Power</th>
<th>CNU</th>
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<th>Power</th>
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<td>1.2</td>
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</tbody>
</table>

### Gas Sector Problems

- Major difference between gas purchased from IOCs and sale price in local market.
- Poor regulation and market structure.
- Short term surplus gas by IOCs.
- Major dispute on cost recovery calculations.
- Scarcity of foreign currency; as a result, 3-6 months payment delay by PB.
- No incentive for IOCs to drill (R/P of 30+ years).
- Mid-term supply shortage, immediate need to drill.
- PB doesn't have high risk investment money or newer technology.

### Gas Sector Reform Strategy

- Formation of regulatory commission.
- Converting all companies under Petrobangla under Company Act 1994, reducing the role of PB as monitor.
- Corporatize PB and redefine role.
- Cost reflective tariff setting.
- Unbundling transmission and distribution.
- Promote private participation in transmission (limited) and distribution under a regulated market.

### Economics of CNG

**The case of Bangladesh**

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What is CNG?
- NG pressurized and stored in welding bottle-like tanks at pressures up to 3,600 psig.
- Typically, same composition as pipeline quality natural gas
- Often used as a vehicle fuel, delivered to an engine as low-pressure vapor (up to 300 psig).
- Note that LPG and LNG are also common transport fuels.

Bangladesh situation
- >15 tcf of proven natural gas reserves
- Domestic consumption preferred
  - Power generation, industrial (fertilizer, etc.) and CNG
- CNG is chosen
  - to create demand for NG
  - to clean the air of Dhaka

General assumptions
- Standard Bangladeshi car (1300 cc with A/C) or equivalent (for electric car)
- 20-year study period
- Load – 10,000 km/year or 200,000 km in 20 years

Diesel assumptions
- Vehicle cost – US$ 10,000
- Fuel efficiency of 10 km per liter
- Diesel/gasoline costs specific to Bangladesh - US$0.48 per liter
- Diesel/gasoline distribution costs as prevailing in the country – 0.5 cents per liter

CNG assumptions
- Standard gasoline car is converted at a cost of US$ 700
- Per vehicle compressor station investment cost is US$ 300
- Compressor station maintenance per year is 5% of initial investment
- Compression cost 20% of natural gas cost
- Fuel efficiency of 10 km per m3
- Transmission using new infrastructure (US$ 0.3/MMBtu)
- Distribution using new infrastructure (US$ 0.6/MMBtu)

EV assumptions
- An electric car costs $12,500
- Fuel efficiency of 5 km per kWh
- Power plant efficiency of 50%
- Generation costs are 1 cent per kWh
- Transmission costs are 1 cent per kWh
- Distribution costs are 2 cents per kWh
- Electricity consumption – 12 kWh per 80 km
- Battery replacement costs US$ 1000 every three years
- Operation and maintenance half that of standard vehicles

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GTL assumptions

- 1 billion dollar investment for a 50,000 bbl/d GTL plant gives US$ 2000 per vehicle investment cost
- Operation and maintenance costs are 5% of the initial investment

<table>
<thead>
<tr>
<th></th>
<th>Conventional diesel or gasoline</th>
<th>CNG</th>
<th>EV</th>
<th>GTL</th>
<th>Cost of NG ($/MM Btu)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$30 oil</td>
<td>$13,123</td>
<td>$13,277</td>
<td>$15,494</td>
<td>$14,693</td>
<td>$1.5</td>
</tr>
<tr>
<td>$40 oil</td>
<td>$13,672</td>
<td>$14,622</td>
<td>$12,994</td>
<td>$14,853</td>
<td>$3.5</td>
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<tr>
<td>$50 oil</td>
<td>$14,210</td>
<td>$15,750</td>
<td>$13,250</td>
<td>$15,853</td>
<td>$3.5</td>
</tr>
</tbody>
</table>

Preliminary results!

Gas cooling

- Commercial & Industrial
- Absorption
- Engine-driven
- Steam-turbine
- Residential

www.gasairconditioning.org

Gas cooling

Payback Calculator

Source: www.gasairconditioning.org
Regulatory/Governmental Incentives To Attract Investment In Natural Gas Distribution Infrastructure

Presented by:
Mark K. Lewis
February 15, 2006

Workshop on Natural Gas Industry for the Ghanaian Delegation by the Center for Energy Economics, Bureau of Economic Geology University of Texas at Austin

Investors/Developers Will Want:
- Stable (or predictable) regulatory regime
- Mitigation of political risk
  - Government will not materially change the rules after the project has been agreed
- Opportunity to earn a reasonable return on investment and to recover investment in a reasonable period of time under the circumstances

Stable Regulatory Regime/Absence of Political Risk
- Once rules are established, rules should remain in place
- Examples:
  - Distributor as merchant or distributor as open access service provider?
  - Either model might work, but if investment is made under one model and then another model is implemented, investor's opportunity to earn return is likely diminished
- Exclusive market must be preserved
- Investor must have right to capture developing market
- Gas infrastructure will likely attract incremental gas consumers
- Cannot permit new loads to bypass distribution system

Stable Regulatory Regime/Absence of Political Risk, cont'd.
- Examples, cont'd.
  - Tariff/Cost Recovery Methodology
    - Reservation charge basis or volumetric basis?
    - Straight Fixed Variable rate design or other?
    - Many examples of components of rates, such as rate base, return, O&M, rate design and taxes
  - Investor can assess economic opportunity and decide whether or not to invest based on known rules
    - If rules change (or even if there is a risk that rules will change), investor's opportunity to earn return is diminished
  - Returns need to reflect risk of material regulatory/governmental changes

Opportunity to Earn a Reasonable Return on Investment and To Recover Investment in a Reasonable Period of Time
- Stable (or predictable) regulatory regime
- Risks must generally be mutually recognized and agreed between regulator and investor
- Level of return must reflect risk

Level of Return Must Reflect Risk
- Trying to attract investor/developer to construct/operate a new gas distribution system
- Higher level of risk than periodic rate case filed by an established gas distribution system
Risk Factors
- Form of cost recovery
  - Reservation charges or volumetric?
- Regulatory risk
  - Might the rules change?
  - Will the change be detrimental to the investor?
- Creditworthiness
  - Will customers pay their bills? Service obligation for customers?
- Construction/Development risk

Risk Factors, con't.
- Size of market
  - What load exists and what load is projected?
  - Need to reward investor for providing backbone for growth
- Exclusivity of market
  - Is there competition? Might there be competition in the future?
- Reward reliability/high-quality service

Level of Return Must Consider Competing Demands on Capital
- Alternate investment opportunities
- If investors can allocate capital where there is less risk for the same or greater return, they will do so
- Investment in a gas distribution system must be an attractive use of capital

Bundled Versus Unbundled Services
- Which model will best attract investors?
- Which model will encourage conversion to natural gas in the marketplace?
- Which model will help make natural gas the fuel of choice in the marketplace?

Regulatory Considerations
- Attract investors by allowing a reasonable return on investment
- Provide a stable and predictable regulatory environment
- Create a regulatory model that maximizes transparency
  - Stakeholders -- regulators, investors, ratepayers -- will be more likely to trust a regulatory regime they understand
## ATTACHMENT 2

### VISIT OF DELEGATION FROM GHANA TO HOUSTON

**February 18, 2005 – March 4, 2005**

### Visitors

- Mr. Seth Adjei-Boye, PURC
- Mr. Emmanuel Quaye-Foli, Ministry of Energy
- Mr. Joseph Essandoh-Yeddu, Energy Commission

<table>
<thead>
<tr>
<th>Date</th>
<th>Activity</th>
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</thead>
<tbody>
<tr>
<td><strong>Feb 18 – Saturday</strong></td>
<td>Arrival</td>
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<tr>
<td><strong>Feb 19 – Sunday</strong></td>
<td>Free day</td>
</tr>
<tr>
<td><strong>Feb 20 – Monday</strong></td>
<td>10:00 – 12:00 Orientation: Discuss program details, tour the office, 14:00 – 16:00 Introductory lecture: Natural Gas Business</td>
</tr>
<tr>
<td><strong>Feb 21 – Tuesday</strong></td>
<td>10:00 – 12:00 Field visit: Hockley, El Paso pipeline control facility 14:00 – 16:00 Introductory lecture: Natural Gas Business (cont’d)</td>
</tr>
<tr>
<td><strong>Feb 22 – Wednesday</strong></td>
<td>10:00 – 12:00 Introductory lecture: Natural Gas Business (cont’d) Visit with Dr. Ben Asante. Work on group project.</td>
</tr>
<tr>
<td><strong>Feb 23 – Thursday</strong></td>
<td>Work on group project. 14:00 – 15:00 Field visit: H-E-B LNG fleet</td>
</tr>
<tr>
<td><strong>Feb 24 – Friday</strong></td>
<td>Work on group project (with Dr. Ben Asante).</td>
</tr>
<tr>
<td><strong>Feb 25 – Saturday</strong></td>
<td>Free day</td>
</tr>
<tr>
<td><strong>Feb 26 – Sunday</strong></td>
<td>Free day</td>
</tr>
<tr>
<td><strong>Feb 27 - Monday</strong></td>
<td>Travel to Austin  10:00 - 12:00 Visit Texas Railroad Commission 14:00 – 17:00 Visit Bureau of Economic Geology, UT-Austin Travel to San Antonio</td>
</tr>
<tr>
<td><strong>Feb 28 – Tuesday</strong></td>
<td>10:00 – 17:00 Visit two LDCs, City Public Service, the local LDC in San Antonio and Grey Forest Utilities, a smaller new LDC northwest of San Antonio. Travel to Houston</td>
</tr>
<tr>
<td><strong>Mar 1 - Wednesday</strong></td>
<td>10:00 – 12:00 Field visit: City of Lake Jackson CNG fleet Work on group project (with Dr. Ben Asante).</td>
</tr>
<tr>
<td><strong>Mar 2 – Thursday</strong></td>
<td>10:00 – 12:00 Field visit: Pickens LNG Facility 13:00 – 15:00 Visit with Mr. Al Boulos and Mr. Terence Barr, Afex International Work on group project.</td>
</tr>
<tr>
<td><strong>Mar 3 - Friday</strong></td>
<td>Group project presentations Wrap up.</td>
</tr>
<tr>
<td><strong>Mar 4 - Saturday</strong></td>
<td>Depart</td>
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What is a "Value Chain?"
- The process of linking specific functions from input through output to delivery, enhancing the economic value of the final product
- Related concepts — "supply chain," "business system," "industry system," "commodity," "commoditization"
- The issue for energy — building value chains around dynamic commodity markets that require fixed infrastructure for physical delivery and "liquidity" for price risk

Generic Value Chain

Vertical Integration: Who Is Better Off?
Source: McKinsey & Company

<table>
<thead>
<tr>
<th>Vertically Integrated Pricing Behavior</th>
<th>1 Integrated</th>
<th>2 Integrated</th>
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<tr>
<td>Upstream costs</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Upstream profit</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Market price for upstream product</td>
<td>50%</td>
<td>50%</td>
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<tr>
<td>Discount to downstream</td>
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<td>5%</td>
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<tr>
<td>Profit paid by downstream</td>
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<td>45%</td>
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<tr>
<td>Other downstream costs</td>
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<td>45%</td>
</tr>
<tr>
<td>Downstream profit</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Downstream costs</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>Price to customer</td>
<td>50%</td>
<td>50%</td>
</tr>
<tr>
<td>&quot;Demand side&quot; customers</td>
<td>50%</td>
<td>50%</td>
</tr>
</tbody>
</table>

U.S. Energy Flow
What is the natural gas business...
...and how should it be regulated?
• Is it a competitive, upstream-driven business?
• Is it an economics of scale, monopoly midstream-downstream business that affects the public interest?
• How much of direct end use and conversion is competitive?
• If the goal is to build the “natural gas factory,” then policy/regulatory approaches need to facilitate value chain development — commercial frameworks.

Building the Natural Gas Factory

International Investor Goals
Commercialize “stranded” natural gas production, by:
• Increasing diversity of midstream options
• Gaining access to downstream participation where supported by markets (“power the world with gas”)
• Export

Worldwide Natural Gas Business System Dynamics: Framework Issues

E&P (LNG)
Profit driven; ROR decision based on expected prices; monetize stranded reserves

Power Generation
Profit driven; ROR decision based on expected prices; fuel competition for gen

Pipelines Transmission
Regulated asset optimization; market rates?

LDG Gas
Regulated asset optimization; proximity to final customers (gas, power); market rates?

End Users
End use based on expected prices; access to competitive supply

Achieving Competitive Supply

Pricing Supply

COMPARATIVE SALES
• Commodity: Molecules
• Third party wholesalers
• A new, mean-reverting global commodity?

The challenges:
• Entry of new suppliers
• Managing common pools
• Developing liquidity to establish locational basis
• Protecting market transparency
• Dealing with third party wholesalers that are affiliated with regulated infrastructure
• Access for new supplies
• Balancing short term cycles and long term capital requirements for resource development

Pricing Transport, Distribution Capacity

RESERVATION (DEMAND)
Fixed cost of investment
• Return on equity, taxes, long term debt, AIG, DA, O&M

COMMODITY (USAGE)
Variable cost of operation
• O&M

CONGESTION MANAGEMENT
“Mean reversion” is a reality if market-clearing participants exist, but is often not captured in capacity pricing

Regulated Infrastructure as the Conduit for Supply Competition

Pricing Transportation, Distribution

RESERVATION (DEMAND)
Fixed cost of investment
• Return on equity
• Taxes
• Long term debt
• AIG, DA, O&M

COMMODITY (USAGE)
Variable cost of operation
• O&M

The challenges:
• Rate-making transitions
• Setting maximum allowable rates with market transparency
• Pricing new capacity
• Dealing with access for new capacity
• Determining contestable transportation markets
• Dealing with market power
• Balancing short term cycles and long term capital requirements for delivery
Achieving Competitive Demand

Pricing Consumption

Market Price
Pricing Margin
Retail Cost
Wholesale Cost

The challenges:
- Political will to allow wholesale price fluctuations to flow to retail users
- Price discovery and transparency
- Market structure (unbundling)
- Market power
- Market oversight
- Balancing short term cycles and long term capital requirements for delivery

Midstream Investment:
Natural Gas Processing

Natural Gas Processing

- Liquefy the heavier molecules that occur in the gas stream in order
  - to make the production more marketable and
  - to increase profits from the lease
- Normally, natural gas consists of about 97% methane (CH₄), 1.5% ethane with the remainder formed by butanes, propane, and larger hydrocarbon molecules.
- "Wet" gas contains a higher proportion of larger molecules as well as oil condensate as opposed to "dry" gas, which contains little or none.

Processing Plants Design

- The composition of the gas stream.
- Recovery of all molecules is possible but raises both capex and opex considerably.
- Liquids prices have been volatile in the past and market conditions are in constant change.
- The location
  - Near the gas field
  - Near the market
- The size
  - Reserve estimates of the field(s)

Processing Technologies

- Mechanical Refrigeration System. This system recovers 30 to 50% of propane and 80 to 90% of butanes at ~20 degrees Fahrenheit.
- Turbo Expander. These type of plants recover up to 99% of propane and between 50 to 90% of ethane.
- Short-cycle Unit (LTX Expansion System). This is mainly used for lean gas systems and recovers 20% of butanes and 80% of gasolines.

Processing Plant Economics

<table>
<thead>
<tr>
<th>Volume (MMscf/day)</th>
<th>100000</th>
<th>3.8 million</th>
<th>3.81</th>
<th>3.52</th>
<th>3.81</th>
<th>3.52</th>
<th>3.82</th>
<th>3.52</th>
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<tbody>
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<td>Year</td>
<td></td>
<td>Investment</td>
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<td>0.10</td>
<td>0.05</td>
<td>0.10</td>
<td>0.05</td>
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<tr>
<td>Sales (MMscf)</td>
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<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
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<tr>
<td>Net Revenue</td>
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<td>0.05</td>
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<tr>
<td>Gross Flow</td>
<td></td>
<td></td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
<td>0.05</td>
</tr>
</tbody>
</table>

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Midstream Investment: Oil and Gas Pipelines

World Oil Trade

World Gas Trade

Worldwide Pipeline Construction (miles)

Pipeline Economics
- Costs associated with pipeline construction depend on many factors.
  - the cost per mile increases with the pipe size.
  - construction on land using a 12-inch pipeline costs about $300,000 per mile while using a 42-inch pipeline costs almost $1.5 million per mile.
  - costs increases if the pipeline goes through residential areas, or there are roads, highways and rivers on the way.
  - costs are dependent on location, terrain, population density, or other factors (for instance, different labor and tax laws in different countries).

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Value Chain
Pipeline Costs

- The most important are material and labor costs - 70 to 80% of the total construction cost both onshore and offshore.
- Surveying, engineering, supervision, administration and overhead, telecommunications equipment, freight, taxes, regulatory filing fees, interest, contingencies (all covered under Miscellaneous).
- Right-of-way (R.O.W.) and damages

<table>
<thead>
<tr>
<th>Estimated Pipeline Construction Costs per Mile and % of Total Onshore</th>
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<tbody>
<tr>
<td>Material</td>
</tr>
<tr>
<td>Labor</td>
</tr>
<tr>
<td>Miscellaneous</td>
</tr>
<tr>
<td>R.O.W. and Damages</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Total</td>
</tr>
</tbody>
</table>

Source: Oil & Gas Journal, Pipeline Economics Survey, various issues.

Maritimes & Northeast Pipeline:
New Gas Production to Established Market

Maritimes & Northeast Pipeline

- Cost of $1.2 billion
- Pipeline length of 1,086 km (663 miles)
- Capacity of 530,000 MMBtu/d
- Placed into service December 1, 1999
- Rate (toll) of $1.20 per MMBtu
- Owners
  - Duke Energy: 37.5%
  - Westcoast Energy: 37.5%
  - ExxonMobil: 12.5%
  - Nova Scotia Power: 12.5%

Maritimes & Northeast Pipeline

- Debt/equity structure of 75%/25%
- Debt
  - US$521.4 million fully amortizing
  - Canadian $712.3 million with 36% balloon payment
  - All debt maturing on November 30, 2009
- Lead banks are
  - Bank of America
  - The Canadian Imperial Bank of Commerce
Maritimes & Northeast Pipeline
- M&NE was the only pipeline linking the Sable fields to natural gas markets
- Because of its importance, Mobil agreed to capacity Backstop Agreements
- Backstop Agreements by Mobil
  - Mobil agreed to purchase approximately 175 MMBtu/d of unsubscribed firm capacity in both Canada and U.S. for 20 years
- Due to the Backstop Agreements, there was no cross default between the physical assets or partnership interests in the U.S. and Canada

Alliance Pipeline System: Unlocking Remote Supply for Established Market

Alliance Pipeline
- Cost of $3.1 billion
- Largest project financed in North America
- Pipeline length of 1,860 miles
- Capacity of 1,600,000 MMBtu/d
- Placed into service December 1, 2000
- Rates (tolls)
  - $0.82 per MMBtu for rich gas
  - $0.73 per MMBtu for lean gas

Alliance Pipeline
- Owners
  - Fort Chicago Energy Partners: 26%
  - Westcoast Energy: 23.6%
  - Enbridge Inc.: 21.4%
  - The Williams Companies, Inc.: 14.6%
  - El Paso Corporation (The Coastal Corporation): 14.4%

Alliance Pipeline
- Debt/equity structure of 70%/30%
- Debt
  - US$961.5 million with balloon payment
  - Canadian $1.6 billion with balloon payment
  - All debt maturing on December 21, 2008
- Lead banks were
  - Bank of Montreal
  - The Bank of Nova Scotia
  - The Chase Manhattan Bank
  - Royal Bank of Scotland

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Value Chain
Exploration and Production

- Much of the time, natural gas is discovered during the search for oil.
- Worldwide proved reserves of natural gas are estimated to be 5919 Tcf.
- Much of this natural gas is "stranded," that is, viable options for commercialization do not yet exist.

Liquefaction

- Natural gas is converted into a liquid state by cooling it to about -256°F. The volume reduces by a factor of 600.
- Liquefaction makes natural gas more economical to transport.
- Currently, there are 16 liquefaction plants worldwide.

Shipping

- LNG tankers are double-hulled ships specially designed and insulated to prevent leakage or rupture in an accident.
- LNG is a cryogenic liquid and it is stored in double-walled tanks at atmospheric pressure.
- The LNG shipping market is expanding.

Regasification & Storage

- At the receiving terminal the LNG is pumped into a double-walled storage tank.
- Vaporized by warming in a controlled environment.
- Vaporized gas is regulated for pressure to enter a natural gas pipeline system (U.S. model) or for immediate industrial/power generation applications.
- Residential, commercial, industrial consumers receive natural gas from imported LNG for daily use from local gas utilities or in the form of electricity.
- Currently, there are about 43 operating regasification terminals worldwide.

How Much Does LNG Cost?

- Natural gas can be economically produced and delivered as LNG within a price range of about $2.00 - $3.70 per MMBtu depending largely on wellhead cost and shipping distances.

LNG Costs are Declining

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LNG Costs are Declining

Minimum Regional LNG Costs

APM in India

APM in India

* Regasification includes pipeline cost from Bahamas

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9

Value Chain
Pressure to reform
- LPG and kerosene enjoyed large subsidies.
- Gasoline attracted enormous surcharges.
- Differential subsidies and taxes on various products led to:
  - misutilization of selected petroleum products
  - burgeoning demand for subsidized products.
- Imports of these products increased.
- Pool account deficit increased from $4 billion in 1997 to $14 billion in 2000.

Deregulation
- Dismantling of the APM is part of a larger reform program that encourages:
  - competition in both upstream and downstream
  - the import of crude oil and products
- In April 2002, the government announced that subsidies for petroleum products would be phased out:
  - except for LPG and kerosene

LPG exception
- Subsidies to be phased out in 3 to 5 years
- Until phase-out, subsidies will be paid out of government funds instead of APM pools
- Subsidies were also increased
- But:
  - New government since the 2002 promise
  - Importance of LPG to large portion of people

LPG Market in India
- LPG demand grew from less than 200,000 tons in 1970-71 to about 5 MMt in 2000.
  - average annual growth rate of ~12%.
- There are around 40 million LPG customers.
- Almost 90% of consumption is residential.
- >20% of supplies are imported.

Growing Demand
- Some 15 million on the waiting list
  - primarily urban middle classes and not the poor targeted by the subsidies
- Government wants to use more LPG in transportation to reduce air pollution.
- Demand is projected to be 10-12 MT by 2006-7.

Reform in the LPG sector
- LPG Order of 1993 enabled private marketers to import, store, bottle and market LPG at market-determined prices.
- In 1993, more than 35 companies were interested in this market.
- But by 1999, private marketers were only able to sign up about one million customers while the public sector companies signed up over 14 million customers.
Reform in the LPG sector

- Private LPG with 23% import duties is much more expensive than subsidized public LPG.
- Only 30% of private LPG capacity is utilized.
- State companies continue to dominate.
- Privatization of some state companies is opposed.
- Government denies import authority to private companies unless they use Indian Oil Corporation for product imports.