Natural Gas 101: The Basics of Natural Gas Production, Transportation, and Markets

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What Is Natural Gas?
Effectively “buried solar energy” from prior geological time periods. Sedimentation and changes in sea levels and geology trapped various organic materials that formed the basis for crude oil and natural gas.

Source: Energy Information Administration
History of Natural Gas

- Natural gas has been known to escape from the surface since ancient Greek, China, and even with Native Americans.
- In 1821 in Fredonia, New York, William A. Hart drilled at 27 foot well in an effort to get a larger flow of gas from a surface seepage of natural gas.
  - This was the first well intentionally drilled to obtain natural gas.
- For most of the 1800s, natural gas was used almost exclusively as a fuel for lamps to light city streets.

Around the 1890s, many cities began *converting their street lamps to electricity*, and therefore gas producers began looking for new markets for their products.

In 1855, Robert Bunsen invented a burner that mixed air with natural *gas—called the “Bunsen burner.”*

- This showed how gas could be used to provide heat for cooking and warming buildings.
- Moving large quantities of natural gas for these new purposes *required pipelines*, though.
- In 1891, there was a *120 mile long pipeline* that carried gas from central Indiana to Chicago.
  - This was one of the first lengthy pipelines built.
• Improvements in metals, welding techniques and pipe making during WW2 made pipeline construction more economically attractive.
• Throughout the 1950s and 1960s, thousands of miles of pipeline were constructed throughout the U.S.
• Today the U.S. pipeline network, laid end-to-end, would stretch to the moon and back twice.

Over time, industry became organized into three components: (1) production; (2) transport/processing; and (3) distribution.
Natural Gas Drilling and Production
Petroleum is recovered mostly through **drilling activities**. This can occur at a few thousand feet to over 20,000 feet.

**Drilling comes after a considerable amount of geological research** and analysis that considers the structural geology (at the reservoir scale), sedimentary basin analysis, reservoir characterization (mainly in terms of the **porosity** and **permeability** of the target structures).

**Porosity** refers to the void space, or the ability of the formation to hold hydrocarbons. **Permeability** refers to ability of a material to allow fluids to flow.

So – how much oil can a structure hold and how does the petroleum flow through the structure.

High porosity and permeability, generally, is a good thing.
Petroleum Formations/Resource Types

Schematic geology of natural gas resources

- Conventional non-associated gas
- Conventional associated gas
- Coalbed methane
- Sandstone
- Seal
- Gas-rich shale
- Tight sand gas
- Oil
Conventional Supply Basins

Traditional basins include the Gulf of Mexico region, onshore Texas/LA, Midcontinent, Appalachia and the Rockies.

Gas Production in Conventional Fields, Lower 48 States

Source: Energy Information Administration based on data from HPDI, IN Geological Survey, USGS
Updated: April 8, 2009
A drilling rig supports a variety of equipment used to physically drill into the earth’s surface to considerable depths. The primary component of the drilling rig is the derrick that supports the drill-string and drill bit as it moves into the earth’s surface.

Source: Energy Information Administration
Drilling is usually completed to **various depths** depending upon initial geological research done at the prospective location. **Vertical wells can range from very shallow, to very deep and are drilled both on-shore and offshore.**

Source: Energy Information Administration
Drilling equipment will be removed from the hole and production casing (or piping) will be lowered into the hole to bring crude oil or gas to the surface and protect subsurface sources of water.

Casing pipe is cemented to ensure strength and well integrity and will be tied into a system of pipes and valves known as a “wellhead.”

The natural pressure in the well will force the oil to the tanks. If the natural pressure is not strong enough, pumps will inject artificial force (or artificial “lift”).
• **Rich/Wet Gas:** raw natural gas with relatively high concentration of heavier hydrocarbons.

• **Lean/Dry Gas:** Raw natural gas with a low concentration of heavier hydrocarbons.

• **Sour Gas:** contains significant quantities of hydrogen sulphide.

• **Sweet Gas:** does not contain significant quantities of hydrogen sulphide.

• **Acid Gas:** contains hydrogen sulphide and carbon dioxide.

• **Non-associated Gas:** found in reservoir in which no crude is present.

• **Associated Gas:** found in reservoir in which crude is present.

• **Solution Gas:** raw natural gas dissolved in crude under reservoir conditions—a type of associated gas.
  - Associated gas not dissolved in crude under reservoir conditions is called “gas-cap” gas.
Unconventional Supplies
Unlike conventional resources, shale plays (natural gas, liquids, and crudes) are located almost ubiquitously throughout the U.S. and are the primary reason for the decrease in overall and regional natural gas prices.
Shale, Horizontal Drilling, and Fractionation

- Shale (unconventional) wells differ from “conventional” wells since they are drilled horizontally and not vertically.

- Horizontal segments are then “fractured” with higher pressure water, chemicals and silica to break up the formation.

- The fractionation process releases/liberates the hydrocarbons.

- Some environmental and water use concerns expressed in some areas of the country on this drilling process.

Source: Energy Tomorrow.
Changes in Reserves and Production

Natural gas production and reserves are at levels not seen since the 1970s and both U.S. natural gas production and reserves are now at an all time recorded peak.

Expanded exploration and development of unconventional resources in increases in natural gas proved reserves in recent years. And, while net additions in shale outpaced the overall decrease in natural gas reserves from all other sources, reserve estimates fell in 2012 due to a 34 percent decrease in the average natural gas price.
Unconventional resources are not a “flash in the pan” and are anticipated to continue to increase over the next two decades or more.

Source: Energy Information Administration, U.S. Department of Energy
Encana reports a reduction in well costs of 15-30% through use of multi-pad drilling, improved rig efficiencies, and lower hydraulic fracturing costs. The use of higher water volumes, increased frac stages, and enhanced pay selection have resulted in 100-150% increases IP rates.

Shale availability will drive U.S. natural gas supply.
Close to 6,000 TCF of shale gas opportunities around the world. Coupled with 9,000 Tcf in conventional suggest a potentially solid resource base for many decades.

Source: MIT Energy Initiative.
Market Organization
Similar to other markets, natural gas markets are comprised of buyers and sellers as well as a number of other market participants that facilitate the transfer (trade) of natural gas commodity to end-users (buyers).
Natural gas is important for all consumers

- Residential
- Commercial
  - Industrial
    - Furnace/Heat
    - Boiler/Steam
    - Feedstock
    - Power Generation
- Power Generation

Natural Gas
Historic Natural Gas Sales Trends

Natural gas sales are not typically volatile over time (unlike prices). Residential/commercial very slow growing, power generation & vehicles represent the growth part of the market.

While the overall gas market has grown little, the composition of use and growth has changed considerably.

Total Natural Gas Delivered to End Users

2000: 21.5 Tcf
2010: 23.9 Tcf

11 percent increase

Percent Change by Sector

- Residential
- Commercial
- Industrial
- Electric Power

Source: Energy Information Administration, Department of Energy
Significant share of natural gas sales are associated with those from residential and small commercial customers which can exhibit fluctuating loads within the year based on seasonality/weather. (low load factors).

Note: power generation demand for natural gas is driven by many of the same underlying factors since generators are dispatched to meet similar loads.
Natural gas demand is influenced by many of the same factors that drive the demand for other goods and services. There are some important differences, however, since natural gas demand is seasonal and highly influenced by the weather.

Natural gas demand determinants include:

- Weather (Heating Degree Days or “HDDs”)
- Overall Economic Conditions
- Natural Gas Prices
- Electricity Prices
- Other Factors
This example shows the variability of sales during the various different hours of the day in prime winter (heating) months. A utility’s supply challenge is to make sure that there enough available natural gas and transportation to move that gas to its customers.
Definition: Natural Gas Commodity

Natural gas commodity originates (physically) from the supply side of the business and is the ultimate product delivered to end users.

Natural gas is traded (and referred to) as a “commodity” because it homogeneous and fungible in nature (non-differentiable on qualitative basis).

Is a highly traded and valuable commodity that can be volatile since prices are set by traders in the market and in its simplest form, represents the price for “as available” commodity. Trades are influenced by the “physical” deliverability that can be constrained.

Physical constraints, coupled with the relatively inelastic nature of demand, can lead to volatile prices.
“Capacity” in the natural gas business refers to the ability to “reserve” or “hold” the ability to move (or call upon) natural gas supplies at any point in time.

Capacity is commonly thought of in terms of transportation (pipe capacity) or storage (cavern capacity), but can also reference the capacity of natural gas supplies (commodity) in the form of “reserves.”

Capacity is not free! You have to pay for the right to call up a resource and hold it in reserve (physical insurance).

While capacity is not free, unused capacity can be resold to the market to offset overall costs.
Natural Gas Transportation & Storage
What is Natural Gas Transmission/Transportation?

Natural gas transmission service is needed to move natural gas from producing areas to consuming areas. The long-distance pipeline is needed to move natural gas from “Point A” to “Point B.”

Natural gas transmission operators receive natural gas from a source by a shipper, then move that gas to a delivery point defined by the shipper. The gas transmission company is paid for moving the gas from receiving the gas at “Point A” and moving that gas to the delivery point at “Point B”.

Natural gas transmission service can be provided on either a “firm” or an “interruptible” basis.
Natural gas infrastructure originates in the producing areas and terminates in (near) consuming areas. The definition of producing areas, and their importance, is changing rapidly with unconventional development.
Direct correlation between the firmness of a service and its price. As quality increases, price increases.

Interruptible rates will tend to be more volumetric in nature.

Firm service rates will tend to have demand (capacity) and smaller volumetric components.
Capacity Markets: The Role of Storage in the Value Chain

Natural Gas Wells → Gas Processing Plant → Main line sales → Natural Gas Company → Underground Storage → Production → Transmission → Distribution → Consumers

Natural gas storage serves two primary functions: to meet seasonal demands for gas (base-load storage); and to meet short-term peaks in demand (peaking storage). Peaks in natural gas demand can range from a few hours to a few days, typically during unusually cold winter weather.

To ensure that adequate natural gas supplies are available to meet seasonal customer requirements, underground natural gas storage facilities are filled during low utilization periods in what is commonly called the “injection season,” typically between April through October of any given year.

Natural gas that is placed into storage is ultimately moved to markets to supplement domestic production and imports during what is referred to as the “withdrawal season” between the fall/winter peak usage months of November to March.
<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Description</th>
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<tbody>
<tr>
<td>Storage Capacity</td>
<td>Usually thought of in terms of base, working and total. (Measured in billion cubic feet or “Bcf”)</td>
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<tr>
<td>Deliverability</td>
<td>Where and how storage is integrated with the transportation system.</td>
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<tr>
<td>Cycles</td>
<td>Number of times a facility can be completely filled and emptied (or “turned”).</td>
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All of these characteristics are important in defining different types and purposes for underground natural gas storage.
Why do we store natural gas?

(1) Reliability: insurance on supply interruptions (outages/curtailments).

(2) Risk management: insurance on rapid and large price changes (volatility).

(3) Profitability: opportunities for storage service sales related to market changes.

Greater price uncertainty and volatility often leads to more significant storage needs.
Fundamental purpose of storage is to provide natural gas during peak demand periods (i.e., reliability).

Storage is needed to meet those peak usage periods when natural gas demand exceeds natural gas supply.

### Capacity Markets: Storage Facility Types

<table>
<thead>
<tr>
<th>Facility Type</th>
<th>Characteristics</th>
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<tbody>
<tr>
<td>Depleted Reservoirs</td>
<td>• Most common - has slower injection/withdrawal rates.</td>
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<tr>
<td></td>
<td>• Conversion of a natural gas field from production to storage duty takes advantage of existing wells, gathering systems, and pipeline connections.</td>
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<td></td>
<td>• Some reservoir storage along the GOM.</td>
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<tr>
<td>Aquifers</td>
<td>• Usually used only in areas where there are no nearby depleted reservoirs.</td>
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<tr>
<td></td>
<td>• Single withdraw period (winter) &amp; used to meet peak load requirements as well.</td>
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<tr>
<td></td>
<td>• Least desirable and most expensive type of natural gas storage facility.</td>
</tr>
<tr>
<td>Salt Caverns</td>
<td>• Very high withdrawal and injection rates.</td>
</tr>
<tr>
<td></td>
<td>• Most salt caverns/domes in U.S. along GOM.</td>
</tr>
<tr>
<td></td>
<td>• More expensive, but faster and more flexible.</td>
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<td></td>
<td>• The safest form of natural gas storage if originally designed for that purpose.</td>
</tr>
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Important Market/Regulatory Distinctions (Gas & Power)

**Wholesale Market**
- Not end-users: are entities that buy or sell for others to make a profit (or lower costs).
- Engaged in interstate commerce: federally regulated
- Examples: Marketers, Utilities, Municipals/Cooperatives

**Retail Market**
- End-users: Purchase energy for use.
- Intrastate transactions: state regulated
- Examples: Residential, Commercial, Industrial
The competitive wholesale market is “upstream” of the transmission and distribution system and is where various market participants generate and trade electricity.
Regulation: Wholesale versus Retail

FERC regulates wholesale (national) markets and state commissions regulate retail (intrastate) markets.

Wholesale – Federal Energy Regulatory Commission

Retail – State Regulated

Regulators

Utility

Utility

Utility
Wholesale (Interstate) Regulation
Natural gas transmission systems can be either *interstate* or *intrastate* systems. Interstate systems are regulated by the Federal Energy Regulatory Commission ("FERC") as a natural monopoly whereas intrastate systems are typically regulated by state utility commissions. (Natural Gas Act of 1938, Federal Power Act of 1935).

At one time, natural gas transportation systems were *integrated* where pipelines owned (contracted for) the commodity and made those "*bundled*” sales to local distribution companies. Sales were “bundled” meaning that transportation and commodity were charged on one integrated rate.

The trend towards *less regulation* and *more competition* in the late 1970s and early 1980s began the process of "*unbundling*” these systems: separating the *commodity* from the *transportation* component. Began the process of turning the interstate pipeline system into a *common carrier-based system*.

While the FERC has a number of “traditional” ratemaking (rate setting functions) it has increasingly moved away from very stringent methods of economic regulation and focus more on market oversight and stimulating competition.
Order 636 (1992) major regulatory change - creates a **common-carrier framework** for transportation. Prohibits pipeline companies from engaging directly in commodity sales and to provide transportation and storage service on **equal and non-discriminatory terms**.

Requires pipeline to provide **“no-notice” transportation service**, **access** to storage facilities, increased **flexibility** in receipt and delivery points, and **“capacity release”** programs.

**No-notice transportation services** allow LDCs and utilities to receive natural gas from pipelines on demand to meet peak service needs for its customers, without incurring any penalties. These services were provided based on LDC and utility concerns that the restructuring of the industry may decrease the reliability needed to meet their own customers' needs.
Order 636 initiated a broad platform for trading a wide range of transportation and storage services that are differentiated on price and quality (firmness) – no longer “plain vanilla” transportation.

Electronic Bulletin Board (“EBB”): post critical information about pipeline operations, services, terms and conditions, market opportunities, and other information. Goal: increase market transparency and reduce informational and transactions costs.

Capacity release: allow the resale of unwanted pipeline capacity between pipeline customers. A customer requiring pipeline transportation can refer to these bulletin boards, and find out if there is any available capacity on the pipeline, or if there is any released capacity available for purchase or lease from one who has already purchased capacity but does not need it.
Retail (Intrastate) Regulation
Regulation conducted by state “Public Utilities Commissions” or “Public Service Commissions” that have quasi-legislative and quasi-judicial functions. Commissioners are appointed or elected. Rates typically set on a “fair” rate of return hence the reference “rate of return regulation.” “Rate of return” regulation is a bit of misnomer since service rates are what are fixed (through a tariff) and actual rates of return (profit/earnings) vary.
Overall, the regulatory process is said to be governed by what is often referred to as the “regulatory compact” between regulators and regulated firms stating:

Utilities are given a monopoly service territory and are allowed to utilized a set of regulated rates that provide them with an opportunity to recover their prudently-incurred expenses and a return “on” and “off” their prudently-incurred investments in return for providing safe, economic, and reliable service.

This “regulatory compact” is the result of over 100 years of regulation. It is not necessarily defined in a specific code or statute, but the result of long-standing practices and precedents.

Rates are set in a fashion that is supposed to be consistent with this regulatory compact.
Utility regulation is **not limited to just setting rates alone.**

State PSCs are very active in the **utility supply planning process.** Will review, evaluate and approve fuel procurement plans of utilities to ensure that they are diversifying their supplies, storage and transportation alternatives adequately.

PSCs will also be active in **integrated resource planning.** This usually involves the analysis current mains extensions plans, other long run capital management/budgeting plans, load forecasts and potential growth requirements, energy efficiency requirements.

PSCs will also be active in the review and monitoring of a utility’s **distribution integrity management** (“DIMP”) plans to ensure that the utility is maintaining a safe and reliable systems. Evaluate and measure existing system, **identify and quantify known threats to the system,** develop plans to mitigate those risks (communication with contractors, asset replacement), evaluate the success of prior plans and strategies, feed those back into upcoming plans.
Conclusions
Natural gas industry a very unique “American” energy industry that is rich and diverse in its players and reflected by three major sectors: production; transmission/storage; and distribution.

Natural gas supplies are abundant and could supply up to a century’s worth of domestic supplies to U.S. consumers at affordable and relatively less volatile prices.

Natural gas end-uses are increasing given natural gas’: (a) affordability; (b) availability; and (c) environmental attributes.

The industry is regulated by a number of agencies at the federal and state level. State PSCs are very important players associated with industry regulation and oversight.
Questions, Comments and Discussion

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