NATURAL GAS 101

Prepared for:
U.S. Department of Energy
Oil and Natural Gas Sector Coordinating Council
## Presentation Outline

1. Overview
2. Production & Processing
3. Transmission & Storage
4. Distribution
5. Liquefied Natural Gas
6. Industrial Control System
What is natural gas?
- Odorless, colorless, naturally-occurring hydrocarbon consisted mostly of methane (70-90%) and other gases.
- Found in reservoirs deep within the earth and brought to surface through production wells.

Where does the U.S. get its natural gas from?
- Domestic production: ~ 90%
- Import from Canada through pipeline: ~ 8-9%
- LNG import from other countries: ~ 1-2%

What makes natural gas a “clean fossil fuel”?
- Natural gas is the cleanest burning fossil fuel, emits 50% less CO2 than coal and 30% less CO2 than oil, and has no mercury emissions.
Natural Gas Production in the World

World Dry Gas Production by Region (2010)

- North America: 29 trillion cubic feet
- Europe: 11
- Former Soviet Union: 26
- Asia: 15
- Middle East: 17
- Africa: 7
- Central & South America: 5
- Oceania: 2

Source: Energy Information Administration
The share of shale gas in total natural gas production in the U.S. is projected to continue to increase, from 40% in 2012 to 53% in 2040.
Natural Gas Consumption in the U.S.

The U.S. consumed more than 23 trillion cubic feet (tcf) of natural gas in 2013.

Source: Energy Information Administration
OVERVIEW

Natural Gas Flow

THE PIPELINE SYSTEM

- **Production & Processing:**
  Natural gas is found in reservoirs deep within the earth and brought to surface through production wells. Gathering lines transport natural gas from wellhead to transmission line.

- **Transmission & Storage:**
  Transmission lines transport natural gas from a gathering, processing or storage facility to a processing or storage facility, large volume customer, or distribution system.

- **Distribution:**
  Delivers natural gas to the consumer (residential/commercial/industrial).

Source: Adopted from American Gas Association and EPA Natural Gas STAR Program
## Key Segments and Functions

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<td>Production &amp; Processing</td>
<td><strong>Production.</strong> Companies explore and drill for natural gas and sell their product to marketers, local distribution companies (LDCs), or end users. (#1 &amp; 2, previous slide)</td>
<td>487,000 production wells</td>
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<td><strong>Gathering System.</strong> Small-diameter pipelines move natural gas from the wellhead to the natural gas processing plant or to an interconnection with a larger mainline pipeline. (#3 &amp; 4, previous slide)</td>
<td>20,000 miles of gathering pipelines</td>
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<td><strong>Processing.</strong> This operation extracts natural gas liquids and impurities from the natural gas stream. (#5 in previous slide)</td>
<td>493 processing plants</td>
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<td>Transmission &amp; Storage</td>
<td><strong>Transmission Compression.</strong> The purpose of compressor stations is to maintain the movement of natural gas along the pipeline. (#6, previous slide)</td>
<td>1,400 compressor stations</td>
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<td><strong>Transmission Pipeline.</strong> Large-diameter, long-distance pipelines transport natural gas from the producing area to market areas. (#7, previous slide)</td>
<td>305,000 miles of transmission lines</td>
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<td><strong>Underground Storage.</strong> Natural gas is stored in depleted oil and gas reservoirs, aquifers, and salt caverns for future use. (#8, previous slide)</td>
<td>400 underground storage facilities</td>
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<td>Distribution</td>
<td><strong>Distribution.</strong> Natural gas utilities typically transport natural gas from delivery points located on interstate and intrastate pipelines to households and businesses through small-diameter distribution pipelines. (#9 through 13, previous slide)</td>
<td>2.2 million miles of distribution pipelines; 1,200 LDCs</td>
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* Approximate/estimated data available as of May 2012.
Sources: Energy Information Administration; Pipeline and Hazardous Materials Safety Administration
Natural Gas Production & Processing

Simplified Illustration of Natural Gas Flow

Production

Transmission

Distribution

Source: Natural Gas Council

Natural Gas Production Segment Includes . . .

Production ➔ Gathering ➔ Processing

U.S. DEPARTMENT OF ENERGY

DRAFT 7/1/2015
Production & Processing

- 1. Drilling & Well Completion
- 2. Producing Wells
- 3. Gathering Lines
- 4. Field Compression (includes, wellhead, gathering, plant inlet) & Treating/Dehydration
- 5. Gas Processing Facility
Three categories of natural gas produced in the U.S.

- Non-associated gas that occurs in conventional gas fields.
- Associated-dissolved gas that occurs in conventional oil fields.
- Unconventional gas that occurs as coal-bed methane, tight gas, shale gas, and associated-dissolved gas in tight oil.
After discovery, completion of a well gas is brought to the surface to begin its pipeline journey to its final destination.

Natural gas does not require refining in the sense crude oil does, but it does require cleaning, due to the presence of other gases and liquids. These gases are removed at a gas processing plant.
WELL CONSTRUCTION: PREPARATION & DRILLING

1. All operations at the site must comply with federal law, state law, and corporate policies incorporating good industry practices.

2. Companies plan with communities to reduce noise and traffic disruptions.

3. The land needed for well construction is cleared and the well is drilled.

4. To protect water, state regulations based on local geology may specify important construction details like the depth, strength, and cementing of casing.

5. Any waste from the well site is disposed of according to federal and state safety and environmental regulations.

6. The well must pass operator testing and inspection before hydraulic fracturing.

Source: American Petroleum Institute
SPOTLIGHT

- Over 1 million wells have been constructed and hydraulically fractured since the 1940s.
- A typical natural gas well is constructed with 3 million pounds of steel and cement.
- Each layer of steel casing is cemented into place to create a seal that is air tight.
- A horizontal well is drilled like a conventional vertical well until it reaches a kickoff point where it extends horizontally.
- The kickoff point is normally over a mile below the surface.

Source: American Petroleum Institute

REGULATED BY JURISDICTION

- Well Construction:
  - Material selection;
  - Performance;
  - Evaluation* - e.g., cement quality,* casing and cementing depth,* etc.
- Well integrity*: Protect groundwater through combination of redundant steel casing and cement sheaths,* mechanical isolation devices*
- Well testing and logging*

*Also covered by API Standards, Recommended Practices, or Guidance
In 2013, more than 70% of all natural gas production in the U.S. came from the following six States.

- Texas
- Pennsylvania
- Wyoming
- Oklahoma
- Louisiana
- Colorado

Source: Energy Information Administration
Gathering Pipelines
• Small diameter pipelines directly connect to the production area, transporting raw natural gas to a common location for processing and treating.

Field Compression
• Typically used to allow a gathering system to operate at a lower pressure or provide sufficient discharge pressure to deliver natural gas into a higher pressure system.

Treating and Dehydration
• To meet downstream pipeline and end-user natural gas quality standards, the natural gas is dehydrated to remove the saturated water and is chemically treated to remove the carbon dioxide and hydrogen sulfide from the gas stream.

Processing
• Once the contaminants are removed, the next step involves the separation of pipeline quality residue gas from mixed NGLs, a method known as processing.

The following is an overview of the path natural gas travels after production. Details provide in next few slides.
A natural gas pipeline system begins at a natural gas producing well or field. The first component of the pipeline system is a gathering line, usually of 12 inches or less in diameter. Gathering lines link production areas to central collection points and can include processing facilities. A gathering system needs field compressors to push gas through the lines (see next slide).

Compression prior to the transmission line is considered “field compression.” (not to be confused with transmission compression, which occurs on the transmission line, not gathering line) Three segments of field compression are required:

- **Wellhead**: To boost the pressure of natural gas from the wellhead for subsequent reinjection for pressure maintenance or gas lift operations.
- **Gathering**: To combine gas flowing from several wells into a gathering line headed for a transmission line.
- **Plant Inlet**: To combine the output of several gathering lines for final gas processing/treating and to boost pressure to enter the transmission pipeline system.

Natural gas must be processed to remove liquids and non-hydrocarbon gases to become pipeline quality. Over 517 processing plants operate in the U.S. with a combined operating capacity of 65 billion cubic feet (Bcf) per day. Although Texas and Louisiana continue to account for the largest portion of U.S. processing capacity, other States have increased their capacity.
A significant percentage of domestic oil and gas production and processing is prone to disruption by hurricanes, because they are located in the Gulf of Mexico and onshore Gulf Coast.

Since 1970, about two dozen major hurricanes (categories 3-5) have made landfall on the shores of Texas, Louisiana, Mississippi, and Alabama, the four states where both off-shore and onshore infrastructure is concentrated.

Other natural hazards, increasing in frequency, include tornadoes, earthquakes, ice storms, and flooding.
Hurricanes Katrina & Rita in 2005.

- Considered the most damaging hurricanes in U.S. history.
- A total of 113 platforms were destroyed and 52 were significantly damaged, while 457 pipelines were damaged.
- Six months after Hurricanes Katrina and Rita, 46 percent of the affected facilities were still shut down.
- However, due to the resiliency of the pipeline network through built-in redundancy and alternate pipeline/supply options, the natural gas market (i.e., end-users) did not experience disruptions.

Source: ICF International
NATURAL GAS 101

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TRANSMISSION & STORAGE

Natural Gas Transmission & Storage

Simplified Illustration of Natural Gas Flow

Production

Transmission

Distribution

Natural Gas Transmission Segment Includes . . .

Transmission

Pipeline Compression

Storage

Source: Natural Gas Council
Transmission & Storage

- 6. Transmission Compressor Station
- 7. Transmission Pipeline
- 8. Underground Storage (geological formations)
Natural gas pipeline transportation system consists of more than 300,000 miles of high-strength steel pipes of 14 to 48 inches in diameter.

It moves natural gas through thousands of miles from producing regions to local natural gas utilities and directly to large end users.

Most pipelines are buried below ground.

Source: Energy Information Administration
A line pipe is manufactured from carbon steel and is made to strict engineering and metallurgical specifications developed by the American Petroleum Institute.

The size of interstate pipelines varies, ranging up to 48 inches in diameter.

Pipeline coating: Prevents external corrosion by prohibiting moisture from coming into direct contact with the metal, providing electrical insulation between the pipe and soil.
Compressor stations boost the pressure in a natural gas pipeline and move the natural gas downstream.

The size of the station and the number of compressors vary, based on the diameter of the pipe and the volume of gas to be moved.

Compressors run continuously or at variable loads to match changing natural gas demand patterns.

Most compressor units are driven by engines or turbines fueled by natural gas (extracted from the pipeline flow). For environmental reasons, the use of electric motors to drive compressor units has been growing.

Note: Station Mainline natural gas pipeline entering the Gallion Compressor station near DeMopolis, Alabama, with a view of the scrubber towers and filter units used to eliminate contaminants prior to compression operations. Courtesy Southern Natural Gas Company, El Paso Corporation. Source: Energy Information Administration.
Compressor stations are installed typically every 50 to 100 miles on a pipeline. More than 1,400 compressor stations exist in the U.S. Basic components of a compressor station are:

- Prime mover (engine, turbine, motor).
- Compressor units.
- Scrubber/filters.
- Cooling facilities, emergency shutdown systems.
- An on-site computerized flow control and dispatch system or Supervisory Control and Data Acquisition (SCADA) system.
Supervisory Control and Data Acquisition, or SCADA, is used to monitor and control certain equipment on the natural gas pipeline system. SCADA transmits operating status, flow volumes, pressure and temperature information from compressor stations, metering & regulation stations and valves to a centralized gas control facility.

• Most compressor stations are unmanned and monitored by an off-site SCADA system that manages and coordinates the operation of the several compressor stations that tie together a natural gas pipeline system.

• For more information, see “Industrial Control Systems” section of the presentation.

Sources: Interstate Natural Gas Association of America
Metering stations measure all natural gas entering or exiting the pipeline system. Meter and regulator stations also include equipment to regulate natural gas pressure and delivery volumes. Pressure regulation equipment ensures natural gas delivered into or out of a pipeline system is maintained within a specified pressure range. This is important for safety reasons, because pipeline systems are designed to operate within specific pressure ranges. Valves along a gas pipeline system provide a means of controlling flow.

Sources: [http://www.energas.co.za/appli.html](http://www.energas.co.za/appli.html)
Natural gas is stored in geologic formations generally thousands of feet subsurface.

Storage plays a key role in balancing supply and demand, particularly during peak-demand periods.

Storage is used to meet seasonal demands, serve fluctuating daily and hourly loads, and to maintain operational flexibility and reliability.

- In general, large volume storage facilities are connected to the interstate pipeline network.
- On average, storage accounts for about 20 percent of the natural gas consumed each winter.


Source: Energy Information Administration
Three key types of underground natural gas storage exist.

- **Depleted reservoirs**: Most existing gas storage in the United States is in depleted natural gas or oil fields.
- **Aquifers**: In some areas, most notably the Midwest, natural aquifers are used for gas storage reservoirs.
- **Salt caverns**: Majority of salt cavern storage facilities have been developed in salt dome formations in the Gulf Coast states.
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Natural Gas Distribution

Simplified Illustration of Natural Gas Flow

Production | Transmission | Distribution

Source: Natural Gas Council

Natural Gas Distribution Segment Includes . . .

Distribution | Storage | Regulator
Natural Gas Distribution

- 9. Distribution Mains/Lines
- 10. City Gate (includes regulators & meters)
- Customers (includes regulators & meters)
  - 11. Large Volume
  - 12. Residential
  - 13. Commercial
Natural Gas Distribution

Distribution is the last step in delivering natural gas to customers.

- Some large industrial, commercial, and electric generation customers receive natural gas directly from high capacity interstate and intrastate pipelines.
- Most customers receive natural gas from their local gas utility, also called a local distribution company (LDC).
- Typically, distribution occurs through smaller pipelines at lower pressures and across shorter distances than transmission pipelines.
- The distribution system consists of more than 1.9 million miles of gas pipes.
- Natural gas can be stored in underground storage (in geologic formations) for use during peak demand.
A city-gate is a custody transfer point from a pipeline transmission company to an LDC. Main lines run up and down the street; service lines run from the main to the houses or businesses.

- Pressure regulators control pressure within a distribution system.
- Metering stations measure natural gas that is consumed by customers.
- Meters measure the gas used at a home or business.

City gate stations serve three purposes:

- Reduce the pressure in the line from transmission levels to distribution levels.
- Mercaptans and other odorants with a distinctive sour scent associated with natural gas are added so that consumers can smell even small quantities of gas.
- Measure the flow rate of the gas to determine the amount being received by the utility.

Regulators are:

- Equipment installed for the purpose of automatically reducing and regulating the pressure in the downstream pipeline or main to which it is connected.
- Include piping and auxiliary devices such as valves, control instruments, control lines, the enclosure, and ventilation equipment.

Source: Pipeline and Hazardous Materials Safety Administration
Gas utilities have a record of extremely high levels of reliability. Most distribution equipment is unmanned and may be monitored/controlled remotely through a SCADA system.

Distribution systems are reliant on the transmission supply. Most distribution pipelines (like transmission pipelines) have 'line pack' as a result of the physical characteristic of natural gas compressibility, which provide a small amount of “real time” storage.

As such, utilities generally have some time to react to system upsets before the pipeline supply is completely exhausted and pilot lights go out. The ultimate objective of every gas utility is to keep customers' pilot lights burning.
LNG is natural gas that has been cooled to about minus 260 degrees Fahrenheit where it condenses to a liquid for shipment and/or storage.

The volume of the natural gas in its liquid state is about 600 times less than in its gaseous form. In this compact form, natural gas can be shipped in special tankers to receiving terminals in the United States and other importing countries. At these terminals, the LNG is returned to a gaseous form and transported by pipeline to distribution companies, industrial consumers, and power plants.

The physical infrastructure of LNG consists of interconnected transportation and storage facilities:

- **Tanker ships**: LNG is transported to the United States in very large, specially designed tanker ships, each sealed and insulated to maintain safe LNG temperature and prevent leakage during transit.

- **Marine terminals**: LNG tankers unload their cargo at dedicated marine terminals which store and regasify the LNG for distribution to domestic markets. These terminals consist of docks, LNG handling equipment, storage tanks, and interconnections to regional gas transmission pipelines.

- **Storage “peak shaving” plants**: More than 100 peak shaving plants supplement pipeline gas supplies during periods of peak demand during winter cold snaps in the United States. During periods of high demand, the LNG is vaporized and injected into either the gas transmission system or a distribution system.
LNG Terminal

Schematic of LNG Terminal

Source: Energy Information Administration

LNG Terminal

Source: Energy Information Administration
In the U.S., there are:

- 8 LNG import facilities; and
- 100 LNG peaking facilities.

“Satellite” storage tanks that depend on other facilities to receive LNG.
LNG Security

The following regulatory bodies oversee/regulate the security and safety of LNG facilities and tanks.

- The International Ship and Port Security code.
- FERC oversees siting of LNG terminals.
- PHMSA oversees LNG facilities and pipelines.
- U.S. Coast Guard regulates LNG safety and security.
- DOE Office of Fossil Energy regulates natural gas imports and exports.
- The Department of Transportation Office of Pipeline Safety regulates the siting and safety of LNG pipeline facilities, including LNG peak-shaving plants.
- The DHS Transportation Security Administration (TSA) and Infrastructure Security Compliance Division (ISCD) regulate different portions of LNG operations.
- The regulation of LNG facilities by states varies from comprehensive to fragmented.
LNG can be used by trucks, railroads, and ships as engine fuel for transportation.

Source: [http://www.lloydslist.com/ll/sector/ship-operations/article380864.ece](http://www.lloydslist.com/ll/sector/ship-operations/article380864.ece)
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A wide variety of Industrial Control Systems (ICS) are used throughout the natural gas industry.

ICS is a general term encompassing a broad group of control systems used in industrial sectors and critical infrastructures.

- Supervisory control and data acquisition (SCADA) systems, generally used to control dispersed assets using centralized data acquisition and supervisory control. Used to control transmission and distribution systems.
- Distributed control systems (DCS), generally used to control production systems within a local area such as a factory using supervisory and regulatory control. Used in gas processing plants and LNG facility control.
- Other control system configurations such as skid-mounted Programmable Logic Controllers (PLC), generally used for discrete control for specific applications and generally provide regulatory control. PLCS are often used within DCS and SCADA systems. Used in compressor station, LNG plants, processing plants, etc.

The primary difference between a DCS and a SCADA system is that a DCS is usually confined within a facility or plant whereas a SCADA system is geographically distributed.

- SCADA systems are highly distributed systems used to control geographically dispersed assets, often scattered over hundreds of miles, where centralized data acquisition and control are critical to system operation, such as managing gas flow or interstate gas transmission system.
- ICSs are used in critical infrastructure sectors including electric, water, oil and natural gas, chemical, transportation, etc. and are often highly interconnected and mutually dependent systems.
In the past, ICS in general (including SCADA) operated in isolated environments, and rarely shared information with systems outside their environment.

Today, however, more components of control systems have become interconnected with the outside world using Internet-based standards, and as control networks have become integrated into larger corporate networks in order to share valuable data, thus the probability and risk of a cyber attack has increased.

A SCADA system usually consists of the following subsystems.

- A Human-Machine Interface or HMI is the apparatus (software and hardware) which presents process data to a human operator, and through this, the human operator monitors and controls the process.
- A supervisory (computer) system, gathering (acquiring) data on the process and sending commands (control) to the process.
- Remote Terminal Units (RTUs) connecting to sensors in the process, converting sensor signals to digital data and sending digital data to the supervisory system.
- Programmable Logic Controller (PLCs) used in compressor stations and as field devices because they are more economical, versatile, flexible, and configurable than special-purpose RTUs.
- Communication infrastructure connecting the supervisory system to the Remote Terminal Units and remote field site instrumentation.
SCADAs are used in distribution systems such as water distribution, oil and natural gas pipelines, electrical power grids, and railway transportation systems.
The increasing convergence of once-isolated industrial control systems has helped organizations simplify and manage their complex environments. However, connecting these networks and introducing IT components into ICS brings unintended security challenges due to potential vulnerabilities, such as:

- Increasing dependency on automation and industrial control systems.
- Insecure connectivity to external networks.
- Usage of technologies with known vulnerabilities, creating previously unseen cyber risk in the control domain.
- Some control system technologies have limited security and are often only enabled if the administrator is aware of the capability (or the security does not impede the process).
- Some control system communications protocols do not have basic security functionality (i.e., authentication, authorization).
- Considerable amount of open source information that is available regarding industrial control systems, their operations, and security vulnerabilities.

Good cyber security programs encompass both IT and ICS. Operators are encouraged to participate in ICS CERT or other threat sharing resource.
Changing Production Profiles.

- Production from large onshore shale basins is shifting the focus of U.S. production from the Gulf of Mexico (GOM), where it has been for the last two decades, to onshore regions.
- Between 2005 and 2011: GOM production declined by approximately 42% (from 9 Bcf/day to 5 Bcf/day) while onshore production (lower 48 States) increased by approximately 43% (from 40 Bcf/day to 60 Bcf/day).
- The growth of Appalachian Basin shale gas, which is reducing the need to move gas from the Southwest and Rockies to the Northeast.

Natural Gas and Electricity Interdependency.

- Growing relationship between the gas and power infrastructures is highlighted by the increased need for new pipeline capacity and high-deliverability storage to match the growth in gas-fired power generation associated with fuel.
- The degree to which this interdependency stresses both the gas and power infrastructures and creates conditions where the infrastructures and related contracting, legal and regulatory structures may be inadequate is not fully understood.
Final Thoughts / Questions