· Introduction
  · What is underground gas storage?
  · Why do we need underground storage?
  · History
  · Natural Gas Trends

· How is Gas Stored Underground
  · Operation Basics
  · Types of Gas Storage

· Risks and Regulation
INTRODUCTION
WHAT IS UNDERGROUND GAS STORAGE?

- **Purpose:** Storage fields act as underground warehouses that allow consumers to have a steady supply of natural gas year-round without interruption.

- **Need:**
  - Balance a variable demand with a near-constant supply.
  - Quicker delivery
  - Handle supply interruptions.
  - Take advantage of expected price changes.

Approximately 20% of all natural gas consumed during the five-month winter heating season is supplied by underground gas storage.
First successful gas storage project completed in 1915 in Ontario in an operating gas field.

Following year, operations began in the Zoar field (depleted reservoir) near Buffalo, NY.

The U.S. has 400 underground gas storage projects – more than any other country.
Natural Gas Uses

- Vehicle Fuel
- Residential
- Commercial
- Electric Power

U.S. Natural Gas Consumption

Source: EIA 2014

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Natural gas use for electric generation up 56% since 2000

Source: EIA 2016
HOW IS GAS STORED UNDERGROUND?
**Method:** Gas injected and stored under pressure so it can be withdrawn as needed.
- Injection/Withdrawal Wells
- Observation Wells

**Cushion (Base) Gas**
- Stored and native gas needed as a permanent inventory in a storage reservoir to maintain adequate reservoir pressure and deliverability rates.

**Working Gas**
- Volume of gas above the designed volume of cushion gas.

**Storage Cycling**
Since 2000: Total Capacity ↑12%, Working Gas ↑22%

Natural Gas Volume (TCF)

Source: EIA 2015
WHAT MAKES A GOOD STORAGE FACILITY?

**Geography & Geology**

- **Geography**
  - Near consuming regions or industry (natural gas-fired power plants).
  - Close to pipelines and distribution systems.

- **Geology**
  - Porosity – how much volume can be stored.
  - Permeability – determines the rate at which natural gas may be injected or withdrawn.
  - Confinement – ability to hold gas in the reservoir.

**Underground Storage Types**

- Depleted Oil and Gas Fields
- Aquifers
- Salt Caverns
DEPLETED OIL AND GAS FIELDS

- Utilizes reservoirs from which gas or oil has previously been produced.
- Cheap:
  - Existing Infrastructure
  - Known Geologic Characteristics
- Moderate cushion gas requirement (≈50%)
- Moderate Deliverability
- Long Cycle (70-200 days)

Source: ALL Consulting 2016
AQUIFER STORAGE

- Uses overlying formation and groundwater as confinement.
- More Expensive:
  - Geologic characterization needed prior to storage.
  - Inject Cushion Gas
- High cushion gas requirement (≈50-80%)
- Moderate Deliverability
- Long Cycle (70-200 days)

Source: ALL Consulting 2016
- Salt domes and bedded salts.
- Most Expensive:
  - Solution Mining
  - New Infrastructure
- Small cushion gas requirement ($\approx 20-30\%$).
- High deliverability.
- Short Cycle (10-20 days)
UNDERGROUND STORAGE LOCATIONS

- Salt Cavern
- Aquifer
- Depleted Reservoir

Source: EIA 2015

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Intrastate facilities represent 52% of underground storage facilities.

Interstate facilities represent 59% of working gas capacity.

Number of Facilities:
- Intrastate: 208
- Interstate: 192

Source: ALL Consulting 2016
TOTAL WORKING GAS CAPACITY

- Aquifer: Intrastate 0, Interstate 0
- Depleted Field: Intrastate 1,250, Interstate 2,250
- Salt Dome: Intrastate 0, Interstate 0

Source: ALL Consulting 2016
RISKS AND REGULATION
OPERATION RISKS

- Casing or cement failure due to:
  - cracks,
  - corrosion,
  - damage during maintenance activities,
  - natural events.

- **Leaks** in wellhead and surface pipe.

- Issues at surface facilities.

- Migration of gas out of the reservoir through confining layers.
  - Faulting in caprock

- Migration through artificial penetrations

- Unexpected enlargement of salt cavern
  - Brine compensated operation
Location: Los Angeles, CA
- Largest underground natural gas storage facility in California and 4\textsuperscript{th} largest in the U.S. (Working Gas)

Date: October 2015

Incident: gas leak resulting in 4,400 households being evacuated.

Cause: Casing failure
- Drilled in 1953, converted to gas storage well in 1972.

Solution: Well killed in February after 3 months.

Volume Released: \approx 5 \text{ bcf}
MOSS BLUFF STORAGE FACILITY

• **Location:** Liberty County, TX
• **Date:** August 2004
• **Incident:** Explosion and wellhead fire
• **Cause:**
  - Separation of the production casing inside the cavern,
  - Breach of the 8-inch brine piping above ground, and
  - Leak between master valve and emergency shut-off on wellhead.
• **Solution:** Fire extinguished after 6.5 days and replacement valve installed.
• **Volume Released:** 6 bcf
YAGGY STORAGE FIELD

- **Location:** Hutchinson, KS (salt cavern)
- **Date:** January 2001
- **Incident:** Explosions due to natural gas migrating underground and into abandoned wells.
- **Cause:** Wellbore failure
- **Solution:** Seal cavern, relieve pressure, plug abandoned wells
- **Volume Released:** 143 mmcf
REGULATION OVERVIEW

- **Intrastate vs Interstate**
  - FERC is the regulatory agency for Interstate facilities.
  - States generally regulate intrastate facilities within their boundaries.

- **Intrastate Regulatory Authority**
  - Oil and Gas Departments
    - wells
    - reservoirs
  - Utility Commissions:
    - Surface facilities
    - Transmission Lines
    - Pricing
REGULATORY PROGRAMS

Regulatory Aspects

- Internal Mechanical Integrity
- External Mechanical Integrity
- Pressure Monitoring
- Corrosion Control
- Wellhead Configuration
- Inspections/Testing
- Contingency/Emergency Plans

Reporting and Enforcement
CURRENT REGULATORY EFFORTS

- States reviewing and revising regulations.
- API RP’s 1170 and 1171 (September 2015)
- U.S. Senate SAFE PIPES Act (December 2015)
  - Directed PHMSA to promulgate nationwide minimum standards for management of underground storage.
  - Could potentially result in the API RPs being the required national standard.
- PHMSA Advisory Bulletin (February 2016)
  - Reminder for operators to review operations and identify potential leaks and failures.
    - Mechanical Integrity
    - Monitoring and Inspections, etc.
  - Encourages operators to voluntarily implement API RPs.
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CITATION INFORMATION: