Unconventional Oil & Gas

Outline

Enhanced Oil Recovery
Unconventional Oil and Gas
Horizontal Drilling
Software

Based on
Improving Oil Recovery

1. Primary recovery: Using pressure in the reservoir or a pump to bring oil & gas to the surface.
2. Secondary recovery: Flooding with water to increase reservoir pressure.
3. Tertiary recovery: Introducing chemicals, gas or heat to decrease viscosity to facilitate the flow.

In primary recovery 30-35% of oil and 80% of gas is recovered. After primary recovery, there still is significant oil to recover; not so for gas.

The general idea is to increase the pressure in the reservoir and to push the oil by using an agent.

**Waterflooding:** Water sweeps the oil towards the oil producing wells.
- Water should not contain suspended solids; otherwise, it decreases permeability.
- Use filtered water.
- Use biocides to kill bacteria that can produce organic slimes (glue-like collection of a bacterial colony).
- Remove oxygen from water to avoid corrosion.
Injection Well Configurations

Five spot pattern: A well is surrounded by 4 wells of the other type.

Staggered line drive

Direct line drive
Enhanced Oil Recovery: Miscible Gas

Miscible (Homogenously Soluble) Gas Drive

- Gas should
  - be noncorrosive (Non sulfates).
  - not mix with the natural gas in the reservoir to explode (Not oxygen).
  - be inexpensive (Not a noble gas such as argon).

- Carbon dioxide satisfy these criteria. It is available from combustion of oil/gas/coal.
  - Carbon dioxide has low viscosity so can pass through injection well towards producing well too fast without releasing trapped oil. To avoid this, water and carbon dioxide can be injected in alternate, which is called WAG (water alternating gas) process.

- Nitrogen also satisfies the criteria but must be obtained from air through separation.
  - Cantarell oil field in Gulf of Mexico continental shelf was found by fisherman Rodesindo Cantarell.
  - It is operated by Pemex and produced 1.16 million barrels per day in 1981
  - It is injected with Nirogen starting in 2000.
  - It reached peak production of 2.1 million barrels per day in 2003.
  - Since then production is declining steeply!
Enhanced Oil Recovery: Chemicals

Chemical flood where different fluids are injected in batches (slugs):

- First, a **slug of water** to condition the reservoir
- Second, a **slug of Alkaline Surfactant** (NaOH or Na$_2$CO$_3$) to reduce tension between the trapped oil and water, in turn reaches deeper into formations and hence frees more trapped oil. Oil forms small droplets suspended in water.
  - Surfactants are absorbed by carbonates. Less carbonates in the environment, the better it is. Chemical floods work well in sandstones. Not in limestone.
- Third, a **slug of water with Polymers** increase water viscosity and recovery ratio. Polymers slow down the water in high permeability zones so that water can interact with oil droplets and bring them to the producing well.
  - Without polymers, the water can flow too fast through the path of least resistance without bringing as much oil as possible.
Heavy oil (<20 API) has high viscosity and does not flow to the producing well. Temperature decreases viscosity and increases flow.

**Steamflooding.**
- Use 1 well in cycles: inject steam, wait for soaking and produce. Repeat the cycle 20-30 times.
- Use two vertical wells: Injection well and production well.
- Use two horizontal wells: Steam pipe is 5 meters above the production pipe. Steam (condenses into water) and moves toward the production pipe.
  - Steamflooding is used in Kern River Field in California.
  - Two horizontal well (SAGD for steam assisted gravity drainage) used in Alberta fields in Canada.

**Fireflooding**
- Start a fire through the injection well to burn part of the oil in the reservoir.
- Must pump oxygen into the reservoir to keep the fire burning.
A bit of history
Reservoir Stimulation Dates back to Civil War

- Stimulation of the well by acid or by explosives may appear to be a new idea, but it is an improvement on the idea Colonel Edward Roberts developed during the battle of Fredericksburg, Virginia in 1862 by observing artillery round cuts in the soil.
- Roberts experimented with exploding the wellbore by dropping black powder (gunpowder) pouches at about 150 metre depths. He called these torpedos and patented them.
- Each torpedo was sold at $100-$200 and Roberts asked for 1/15th share of the increase in oil production as a result of torpedos. Although he did not always get his share, he established a company with $300,000 capital:
Unconventional Oil and Gas Reserves and Classification
Unconventional Oil and Gas Reserves

- **Unconventional Gas is**
  - in shale,
  - in ice or coal,
  - in very low permeability reservoir rock such as coal or ice.

- **Unconventional Oil is**
  - in very low permeability reservoir rock,
  - immature as it did not complete its catagenesis stage due to lack of temperature and/or pressure,
    » the source rock may not be as deep as necessary (depth of <2000 meters)
  - degraded after its formation, say by contamination or mixing with sand.

1. Immature oil
2. Shale oil and/or gas
3. Tight (very low permeability reservoir rock) oil and/or gas
4. Tar sands (degraded oil)
5. Gas hydrate (gas in ice); Recall Coal Bed Methane is gas imprisoned in coal by water

- There sometimes is confusion between “shale oil & gas” and “tight oil & gas”. Hydrocarbons in both types of reserves are hard to recover but because of different reasons.
Global Shale and Tight Oil & Gas Basins

Map of basins with assessed shale oil and shale gas formations, as of May 2013

- Prudhoe Bay, Alaska
- Alberta, Canada
- Orinoco Belt, Venezuela
- Amazons, Brazil
- Mexico
- Argentina
- Orinoco Belt, Venezuela
- Amazons, Brazil
- South Africa
- Hunan, China
- Harbin, China
- Mongolia
- Siberia, Russia
- Estonia, Poland
- Romania
- Pakistan
- Libya
- Algeria
- Mexico
- Argentina
- Hunan, China
- Harbin, China
- Mongolia
- Siberia, Russia
- Estonia, Poland
- Romania
- Pakistan
- Libya
- Algeria
- Mexico
- Argentina
- Orinoco Belt, Venezuela
- Amazons, Brazil
- South Africa

Legend:
- Assessed basins with resource estimate
- Assessed basins without resource estimate

Source: United States basins from U.S. Energy Information Administration and United States Geological Survey; other basins from ARI based on data from various published studies.
1. An Immature Basin and Mostly Tight Basins

1. Immature oil

Piceance basin at the corner of CO, WY, UT.
Organic material: Algae.
Inorganic material: Calcareous muds & salts.
Inorganic material deposited over organic material to start oil formation but the inorganic material was shallow - not enough to generate heat/temperature for a full maturation of the oil. The incomplete maturation gave kerogen, not oil. Heating kerogen up to 350 °C can produce oil.
To obtain oil, fireflooding or cracking.

Heating kerogen up to 350 °C can produce oil.

Whitish Calcareous Rock
2. Shale Oil and/or Gas

- After oil or gas is generated in the shale (mud-like source rock), it is not released and remains in the shale (reservoir rock) because the shale (the trap) has low permeability.
  - Shale is the source rock, the reservoir rock and the trap, all at once.
- Hydrocarbon in the shales are typically gas which is contained in vertical fractures.

- Frac fluid can be used to open, enlarge fractures and prop them open.
- Frac fluid includes water (~98%),
  - friction reducers (polyacrylamide) for ease of pumping. Acrylamide ($C_3H_5NO$) is neurotoxin & carcinogen but Polyacrylamide is a longer chain and hopefully stable.
  - biocides (glutaraldehyde),
  - oxygen imprisoners (ammonium bisulfate),
  - acids (hydrochloric),
  - propant (quartz sand).
2. Properties of a Shale

- Depth: Shallow shales are easier to access to.
- Organic material content: Organic materials $\uparrow \Rightarrow$ oil/gas $\uparrow$.
- Fraction of natural fractures: High fraction requires less fracking.
- Gas pressure: Higher makes easier recovery.
- Thickness: Thicker shale indicates more reserves.
- Brittleness: If the shale is more brittle, it is less elastic. So it breaks during fracking rather than bending.
  - Shale with higher concentration of calcium carbonate or silica (sand) is more brittle than the shale with higher concentration of clay.

Eagle Ford, West Texas
Depth: 1,220-4,200 meters; deeper in the South.
Shallow areas produce dry gas (methane);
Shallow areas produce oil.
Thickness: 76 meters.
Brittleness: Yes, high calcite content.

Depth: 1,800-3,000 meters.
Shale is rich in liquids.
3. Tight Gas

- Gas can be found in very low permeability sandstones.
- Gas is **trapped in sandstone**; no trap above the reserve is necessary.
- Tight gas sands (sandstone including gas) occur in large and continuous deposits.
  - Granite Wash Tight Gas Sand Reservoir is in the Texas panhandle and Western Oklahoma.
  - Granite Wash happened with the exposure of granite to weathering after Amarillo-Wichita uplift.
  - Reservoir covers more than 5,000 km²; say 100 kms long and 50 kms wide.
  - Depth: 3,300-5,000 meters. Tight gas sands are in multiple layers.
  - Granite Wash has higher porosity and permeability than shale.
  - First drilling in 1954, not economical until slickwater (chemical added water) fracking.
3. Tight Gas

Major Tight Gas Plays, Lower 48 States

Source: Energy Information Administration based on data from various published studies
Updated June 6, 2010
Bakken: Both
2. Shale and 3. Tight Gas

- Depth: 1,500-3,000 meters
- Bakken has three layers:
  - Shale, organic rich, source rock
  - Sandstone, dolomite, limestone, reservoir rock
  - Shale, organic rich, source rock
- Middle layer is the reservoir rock that holds
  - API 41 sweet oil
  - Gas
  - Natural gas liquids
- Reservoir rock thickness 13 meters
- Porosity 5%, very low permeability
- Recovery by horizontal wells and fracking.
More than 11,000 wells … drilled in ND since 2006, … almost 40,000 miles of well bores … end to end, … circling the Earth about one and a half times. G. Aisch. 2014. What North Dakota Would Look Like if Its Oil Drilling Lines Were Aboveground. NYT, Nov 25 issue.
4. Tar Sands

- Tar sands are heavy oil 8-14 API.

Reservoir
- They are mixed with water and sand.
- Degraded oil theory: Tar initially is good quality oil but migrates all the way to the surface in the absence of a trap. On the surface it degrades by mixing with water and sand.
- Depth: 0 meters
- Thickness of surface deposits: 40-60 meters
- Composition: 10% bitumen; 4% water; 86% sedimentary solids.

Recovery
- Mined by shovels and treated with hot water and caustic soda (NaOH Alkaline Surfactant to reduces the tension between the oil and water).
- 90-100% of bitumen floats to the top to be separated from water and sedimentary solids.
- Bitumen is refined (heavy oil refining) to produce 32 API oil.
- 2 tons of oil sands yield 1 barrel of API 32 oil.
Oil Sand Miners in Athabasca

◆ Four active oil sand miners in Athabasca, Northern Alberta, Canada:
  – Syncrude, a joint venture, Canadian Oil Sands is majority owner
  – Suncor Energy
  – Canadian Natural Resources
  – Shell

◆ Imperial Oil controlled by Exxon to show up circa 2012-2013

◆ Total (of France) will be the sixth
  – Approved for $9B Joslyn North mining field
  – Expected to be operational in 2017
  – Mining operation to cover 70 square km to produce 100,000 barrels of oil per day
  – Entire Joslyn field (220 square km) can produce 874 M barrels of bitumen in 20 years

Source: Map of Athabasca and pictures are from Google Earth.
Information is based on “Canada Backs Total’s Oil-Sands Project” by E. Welsch and P. Viera in WSJ Dec 8, 2012
Oil sands projects from Alberta Dept. of Energy
There also is in-situ method, not covered here.
5. Gas (Clathrate) Hydrates

- Gas Hydrate: Gas densely packed in ice.
- When water turns into ice, hydrogen of one water molecule can be attracted by the oxygen of another molecule. This results in a complicated cage structure that is often unstable. Presence of guest molecules inside the cage increases the stability.
- One volume of gas hydrate yields 168 volumes of methane at room temperature and pressure.
- Gas hydrates are in frozen soils (arctics) or deep ocean floor.
- No industrial production is known.
Other bits of history
Technologies to Perforate Casing


  - His device has scissor-like legs that protrude sideways towards the casing when pressure is applied from above, see the original drawing on the right.

- 1930s, people searched for more accurate ways of reaching the reservoir without too much damage to the casing, cement, wellbore and formations around. Drilling also damages the formations within 1-3 feet around the wellbore.
  - Bill Lane and Walt Wells designed a tool that shoots steel bullets through the casing towards the formations. Their tool is illustrated in Popular Science Monthly, 1938.


- 1960, patent US 2,947,250 to Henry H. Mohaupt for “Shaped charge assembly and gun”
  - Mohaupt, a Swiss army veteran, worked for the US Army anti-tank rocket grenade program during WW II that led to 60-mm M1A1 Rocket Launcher (Bazooka)
  - After WW II, Mohaupt worked for Well Explosives Company of Forth Worth.
- Horizontal Drilling
- Perforation
- Hydraulic Fracking at high pressure
- Matrix Acidization at low pressure
Horizontal Drilling

Horizontal drilling is tilting the drill bit so that a non-vertical borehole can be drilled.

Steerable drills (downhole assembly) have hydraulic ability (“sliding mode”) to slowly veer off from the vertical direction towards a horizontal one.

The maximum (build) angle change from the vertical is 20 per 30 meters, if using steel drillpipes.

The hole is vertical from the surface to the kickoff point.

The hole makes a curvature between the kickoff point and entry into the reservoir. Entry point can be called the heel while the end of the hole can be called the toe, think of your foot.

Horizontal drilling is longer and more expensive

Drilling the curvature can require changing downhole assemblies. Drilling the horizontal sections can cause loss in rate of penetration.

Why horizontal drilling? To
Tap into Vertical fractures in the shale
Tap into Multiple zones
Avoid Inaccessible surface continental shelf or a rock, DFW airport
Perforation and Hydraulic Fracking

After horizontal drilling is completed, pull the drill bit out.
- **Completion:** Place metal casing and possibly cement it.
- **Perforation:** Put a plug at the toe (end of the drilled hole).
  - Push the perforation gun all the way in.
  - Repeat for all stages
    - Perforate a stage, pull the gun, plug the perforated stage
    - Pull the perforation gun out of the hole
- At the completion of perforation stage, the part of the pipe in the reservoir has holes that extend towards the formation. But the holes are not wide enough.
- **Drill holes into the formation.**
- **Hydraulic Fracking:** Bring trucks with fracking fluid.
  - To open passages: Pump fracking fluid to formations
    - Fluid at high pressure 5000-6000 psi. Atmospheric pressure 15 psi
  - To keep passages open: Proppant (little sand-like substance)
    - Resin-coated to reduce proppant flowback to reservoir
    - Polymer coated to use recycled / seawater in fracking
  - Pull the fracking fluid out to recycle it
What is in the Fracking Fluid?

- Water and Sand
- **Acids to dissolve minerals and initiate fissures** in rock (pre-fracking)
  - Swimming pool cleaning acid
- Sodium Chloride to allow a delayed breakdown of the gel polymer chains
  - Table salt
- Polyacrylamide to minimize the friction between fluid and pipe
  - Soil conditioner, water treatment agent
- Ethylene Glycol to prevent scale deposits in the pipe
  - Automotive anti-freeze, de-icing agent
- Borate salts to lower fluid viscosity
  - Laundry detergents, hand soap, cosmetics
- Sodium/Potassium Carbonate to maintain effectiveness of other components, such as crosslinkers
  - Washing soda, detergent, soap, water softener, glass, ceramics
- Glutaraldehyde to eliminate bacteria in the water
  - Disinfectant, sterilization of medical and dental equipment
- Guar Gum to thicken the water to suspend the sand
  - Thickener in cosmetics, baked goods, ice-cream, toothpaste, sauces
- Citric Acid to prevent precipitation of metal oxides
  - *To precipitate: to separate a substance in solid form a solution.*
  - Food additive, food and beverages, lemon juice
- Isopropanol to increase the viscosity of the frack fluid
  - Glass cleaner, antiperspirant, hair coloring

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*Volumetric Composition of a Fracture Fluid*

- Water and Sand: 99.51%
- Other: 0.49%

Modified from: ALL Consulting, based on data from a fracture operation in the Fayetteville Shale, 2008
Matrix Acidization and Some Videos

- **Matrix Acidization**: Rather than fracking fluid at high pressure, pump a simpler solution (acid) at lower pressure.
- **Pros**: Acidization maintains gentler than hydraulic fracturing and maintains more of the formation structure.
- **Cons**: The reach of acidization is about 3-4 yards so it is limited with respect to 100 yards of hydraulic fracturing.
- Type of the acid depends on the formation:
  - Sandstone → Hydrofluoric acid
  - Limestone → Hydrochloric acid or acetic acid

Chesapeake Energy hydraulic fracturing: [http://www.youtube.com/watch?v=73mv-Wl5cgg](http://www.youtube.com/watch?v=73mv-Wl5cgg)

Animation of Hydraulic Fracturing by Marathon Oil: [https://www.youtube.com/watch?v=VY34PQUiwOQ](https://www.youtube.com/watch?v=VY34PQUiwOQ), suggested by Byron Stickney, Merit’16

Hydraulic Fracturing 3D Animation with emphasis on contamination: [https://www.youtube.com/watch?v=fFUXq9UolN4](https://www.youtube.com/watch?v=fFUXq9UolN4), suggested by Byron Stickney, Merit’16

Chesapeake Energy horizontal drilling and splitting: [http://www.youtube.com/watch?v=AYQcS27Xp8](http://www.youtube.com/watch?v=AYQcS27Xp8)
# Drilling & Completion Costs for Conventional and Unconventional Wells

## Conventional Well Costs

<table>
<thead>
<tr>
<th>Intangible Costs</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Location</td>
<td>65</td>
</tr>
<tr>
<td>Drilling Rig &amp; Tools</td>
<td>366</td>
</tr>
<tr>
<td>Drilling fluids</td>
<td>116</td>
</tr>
<tr>
<td>Rental Equipment</td>
<td>113</td>
</tr>
<tr>
<td>Cementing</td>
<td>54</td>
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<tr>
<td>Support Services</td>
<td>275</td>
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<tr>
<td>Transportation</td>
<td>83</td>
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<tr>
<td>Supervision</td>
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<tr>
<td><strong>Tangible Costs</strong></td>
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<tr>
<td>Tubular equipment</td>
<td>846</td>
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<tr>
<td>Wellhead equipment</td>
<td>156</td>
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<tr>
<td>Completion equipment</td>
<td>15</td>
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<tr>
<td><strong>Contingency</strong></td>
<td>321</td>
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<tr>
<td><strong>Total</strong></td>
<td>2,440</td>
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## Drilling Intangibles

<table>
<thead>
<tr>
<th>Item</th>
<th>Cost</th>
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</thead>
<tbody>
<tr>
<td>Location</td>
<td>50</td>
</tr>
<tr>
<td>Rig move</td>
<td>60</td>
</tr>
<tr>
<td>Rig</td>
<td>546</td>
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<tr>
<td>Rig crew safety bonus</td>
<td>25</td>
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<tr>
<td>Bits &amp; PHA</td>
<td>79</td>
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<tr>
<td>Fuel</td>
<td>48</td>
</tr>
<tr>
<td>Water</td>
<td>42</td>
</tr>
<tr>
<td>Mud &amp; Chemicals</td>
<td>55</td>
</tr>
<tr>
<td>Cementing</td>
<td>50</td>
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<tr>
<td>Open hole logging</td>
<td>35</td>
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<tr>
<td>Mud logging</td>
<td>19</td>
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<tr>
<td><strong>Contingency</strong></td>
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<tr>
<td><strong>Total</strong></td>
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## Drilling Tangibles

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<th>Item</th>
<th>Cost</th>
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<tr>
<td>Conductor 20”</td>
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</tr>
<tr>
<td>Surface casing 11 ¾”</td>
<td>11</td>
</tr>
<tr>
<td>Intermediate casing 8 5/8”</td>
<td>82</td>
</tr>
<tr>
<td>Wellhead</td>
<td>33</td>
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<tr>
<td><strong>Total</strong></td>
<td>154</td>
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## Completion Intangibles

<table>
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<th>Item</th>
<th>Cost</th>
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<td>Daywork Rig</td>
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<tr>
<td>Bits</td>
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<tr>
<td>Fuel</td>
<td>2</td>
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<tr>
<td>Water</td>
<td>15</td>
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<tr>
<td>Cementing</td>
<td>50</td>
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<tr>
<td>Logging</td>
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<tr>
<td>Perforating</td>
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<td>Acid/Frac</td>
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<tr>
<td>Transportation</td>
<td>5</td>
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<tr>
<td><strong>Contingency</strong></td>
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<tr>
<td><strong>Total</strong></td>
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## Completion Tangibles

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<th>Item</th>
<th>Cost</th>
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<td>Production String 5 1/2”</td>
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<tr>
<td>Tubing</td>
<td>50</td>
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<tr>
<td>Wellhead equipment</td>
<td>10</td>
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<tr>
<td>Tanks</td>
<td>30</td>
</tr>
<tr>
<td>Flow lines</td>
<td>5</td>
</tr>
<tr>
<td>Fittings</td>
<td>30</td>
</tr>
<tr>
<td>Rods</td>
<td>44</td>
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<tr>
<td>Surface pump</td>
<td>125</td>
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<tr>
<td>Subsurface pump</td>
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<tr>
<td>Heater, treator, separator</td>
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<tr>
<td>Metering</td>
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<tr>
<td>Contingency</td>
<td>70</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>575</td>
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</tbody>
</table>

Data are in wellCosts.xlsx

Completion costs ↑ in magnitude & percentage with unconventional wells.
Update 2019
Bakken & Three Forks Formation underneath

Comparison of Bakken wells completed in 2010 & 2017

Faster but shorter recovery with technology

Lower price ⇒ Fewer wells

Doubling proppant use

No significant change in lateral length

x-axis is the quarters in calendar time

x-axis is the number of months since completion

Average of first 6-month production of wells in bbl

Cumulative production of wells in bbl

Source: https://shaleprofile.com

Comparison of Bakken wells completed in 2010 & 2017
In daily & cumulative production since their completion
Hydraulic Fracturing Accidents: Well Blowout

- Well blowout happens due to
  - High pressure in the wellbore and/or reservoir
  - Stimulation by water/fire/explosives increase the pressure
- The casing, when cemented properly, can hold some pressure. But it fails when
  - The cementing (completion) is not perfect or not complete
  - Due to time pressure, there may be a tendency to do some jobs in parallel.
- Clean up is not trivial, see the greenish brown fracking liquid at the wellbore
Oil service companies Schlumberger, Halliburton, Baker Hughes and Weatherford have R & D budgets ↑ & generally number of patents ↑.

Patents are for the technologies presented above and for those that can become commercial in coming years. E & P Technology has been useful to recover oil from shale, which was previously thought as useless soil. E & P Technology has increased the oil supply and destroyed the high prices. Revenge of the Prices: Lower prices force oil service companies to cut R & D budgets.

R&D Budget ↑ ⇒ Patents ↑ ⇒ Reserves ↑ ⇒ Abundance ⇒ Price ↓

Revenge of the Price

R&D Budget ↓ ⇒ Patents ↓ ⇒ Reserves ↓ ⇒ Depletion ⇒ Price ↑
A bit of future
Patents to Perforate Casing

◆ US Patent and Trademark Office approves drilling and perforation related patents under the following classifications
  – Class 175 Boring and Penetrating the Earth http://www.uspto.gov/web/patents/classification/uspc175/defs175.htm
    » Subclass 4.6 Concave-shaped charges
  – Class 166 Wells http://www.uspto.gov/web/patents/classification/uspc166/defs166.htm
    » Subclass 55 Means for Perforating, Weakening, Bending or Separating Pipe at an Unprepared Point

◆ In 175/4.6 and 166/55, some of the latest patents are
    » Awarded to Schlumberger Canada employees Arguello Gerardo, Jason Mai, Wenbo Yang
    » “Shaped Charge assembly system”: A system where a group of substantially universal pre-manufactured explosive pellet assemblies are provided for on-site forming of shaped charges. That is, a specifically tailored liner may also be separately provided to the worksite/oilfield and combined with any one of the pellet assemblies so as to form a shaped charge having characteristics that are determined by the particular liner used. In this manner, hazardous shipping of fully assembled shaped charges may be avoided …
    » Awarded to Geodynamics employees Nathan Clark, Kevin George, James Rollins
    » “Apparatus for creating and customizing intersecting jets with oilfield shaped charges”: A geological perforating tool (gun) shape charges disposed at an angle that provides an improvement over other known embodiments …
Software and Their Vendors for O & G Companies

A software can have
- **Database** capability: Process automation, integration, recording, reporting
- **Analytics** capability: Production, drilling, capacity decision making

- **Seven Lakes Technologies** [www.sevenlakes.com](http://www.sevenlakes.com) has enterprise software for upstream O & G companies
  - Both database and analytics
- **Scout Group** [www.scoutfdc.com](http://www.scoutfdc.com) has a data capturing software
  - Only database
- **Canary Labs** [www.canarylabs.com](http://www.canarylabs.com) has software for process and energy industries, in particular for upstream as well as refining and pipelines
  - Only database
- **Peloton** [www.peloton.com](http://www.peloton.com) has software for drilling and well operations
  - Only database
- **Mi4 cooperation** [www.mi4.com](http://www.mi4.com) has *Productioneer* software to record data locally or on a cloud managed by Mi4
  - Only database
- **Total Stream** [www.totalstream.com](http://www.totalstream.com) has software for drilling, production and finance
  - Database with prediction capability
- **P2 Energy Solutions** [www.p2energysolutions.com](http://www.p2energysolutions.com) has software for land management, production, accounting
  - Database with prediction capability in reservoir management module
- **Halliburton’s Landmark** [www.landmarksoftware.com](http://www.landmarksoftware.com) has software for geosciences, geomechanics, drilling, production and economics
  - Both database and analytics
- **Schlumberger’s Avocet** [http://www.software.slb.com/products/platform/pages/avocet.aspx](http://www.software.slb.com/products/platform/pages/avocet.aspx) is a platform that hosts various integrable software relating to drilling, production, engineering, finance
  - Both database and analytics
Environmental and Earthquake Concerns
Fracking in Pavillion, WY and Poland; Quakes in DFW

- Most fracking is in shale rock that are > 500-600 m deeper than aquifer
  - Encana drilled Pavillion wells
    - Fracked sandstone rock is about 400 m deep
    - Water wells extend to 250 m deep
  - EPA finds contaminants in the water
    - 0.246 g of benzene in 1000 g of water; normal < 0.005 g.
    - Methane, primary component of natural gas.
    - Glycols and alcohols used in hydraulic fracturing fluids.
  - EPA: poor well construction, poor cementing in Pavillion

- EPA fined Encana $371,200 for poor well cementing in Colorado where gas seeped from a well into a creek

- Plus for Environment: Pointing to the geological evidence of climate change at his IHS Energy Conference presentation in March 2014, BHP Billiton CEO Andrew Mackenzie, a geologist by training, says: “You can’t argue with a rock”.

- Minus for Environment: During Ukraine-Russia tension of 2013-14, Poland proposes 6 year tax breaks for shale gas industry. Poland's Environment Minister Maciej Grabowski expects to see some 30 new shale gas drillings carried out [in 2014] after the new, more business-friendly regulations are put on a fast track.

- Earthquakes in DFW: Small 3-4 Richter scale but in a series. Epicenters are significantly closer to surface (1,500 – 4,500 metres deep as opposed to usual quake epicenters of 4,500-15,000 metres deep). DFW suffered > 100s of small quakes since 2008. US Geological Survey is considering to increase earthquake risk level in Dallas.
  - Are the quakes man-made, especially due to fracking activity?
European Regulations on Fracking

Fuel for the future?

- **Shale-gas basins**
- **Extraction:** 2013
- **banned/moratorium**
- **allowed**
- **allowed & permits issued**

*Restrictive laws

Sources: International Energy Agency; KPMG; press reports
Summary

Unconventional Resources

Source: MITEI “Future of Natural Gas” 2010 & Holditch 2006

Deep natural gas
Depth > 5km

Source: A modified EIA figure.