Stanford University

GCEP Global Climate & Energy Project

Energy Supply with Negative Carbon Emissions
GCEP Workshop
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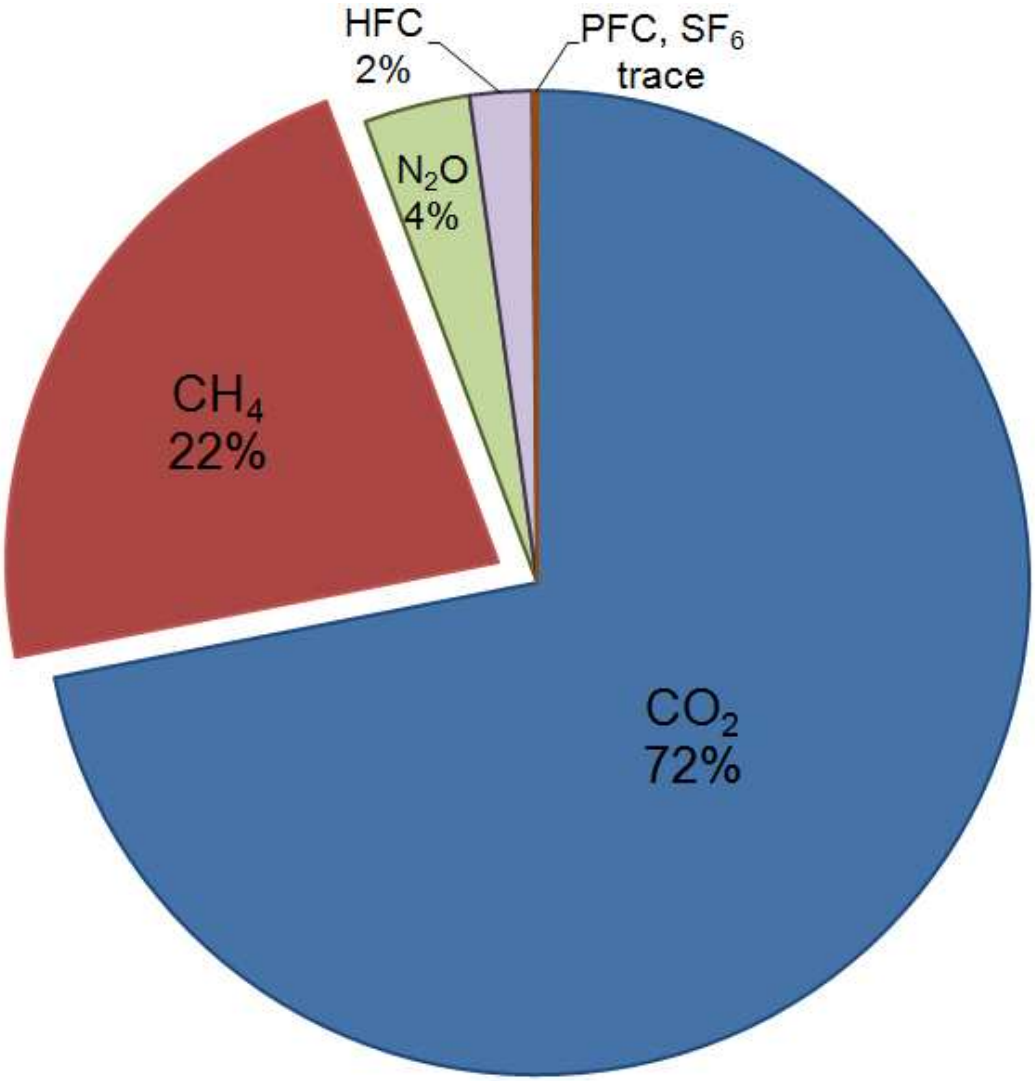
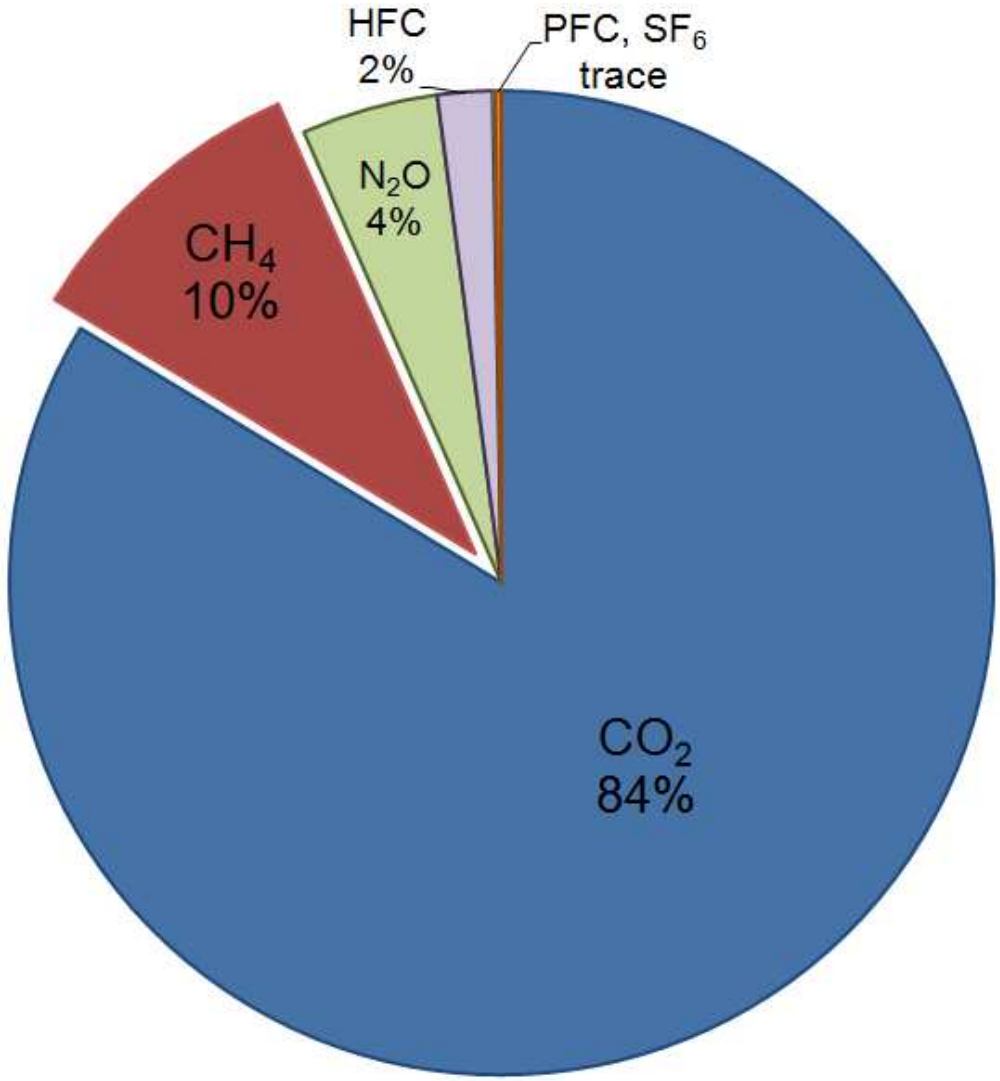
June 15th, 2012

Methane Leakages from Completion of Unconventional Wells

CH_4 as a Mass Fraction of GHG Emissions in the U.S.



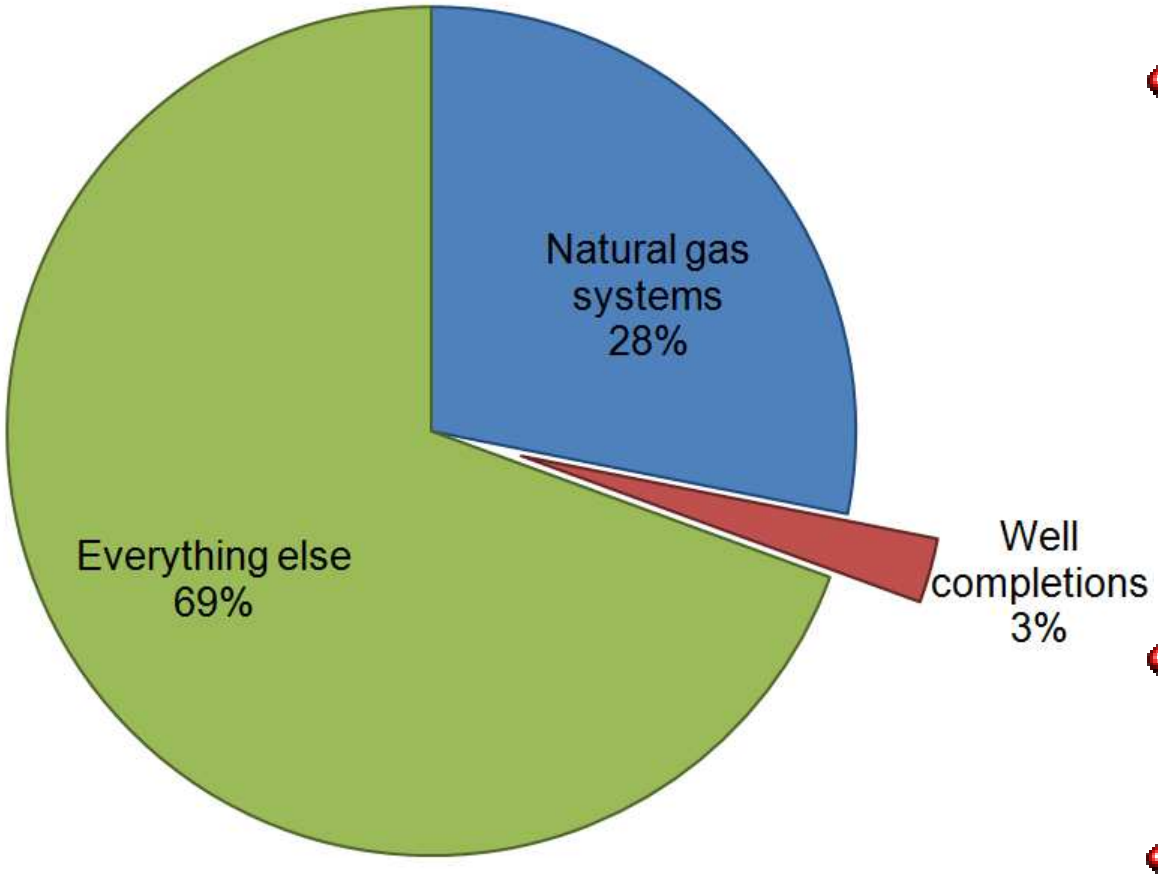
GWP (20 years)



GWP (100 years)

(- GHG emissions, EPA 2010)

CH_4 Emissions from Unconventional Well Completions: Perspectives



Breakdown of annual CH_4 emission sources in the U.S.

- **Emissions from:**

  Unconventional well completions

  - 48 Bcf / yr or 0.9 Mtonnes/yr

  Natural gas systems

  - 550 Bcf / yr or 10.3 Mtonnes/yr

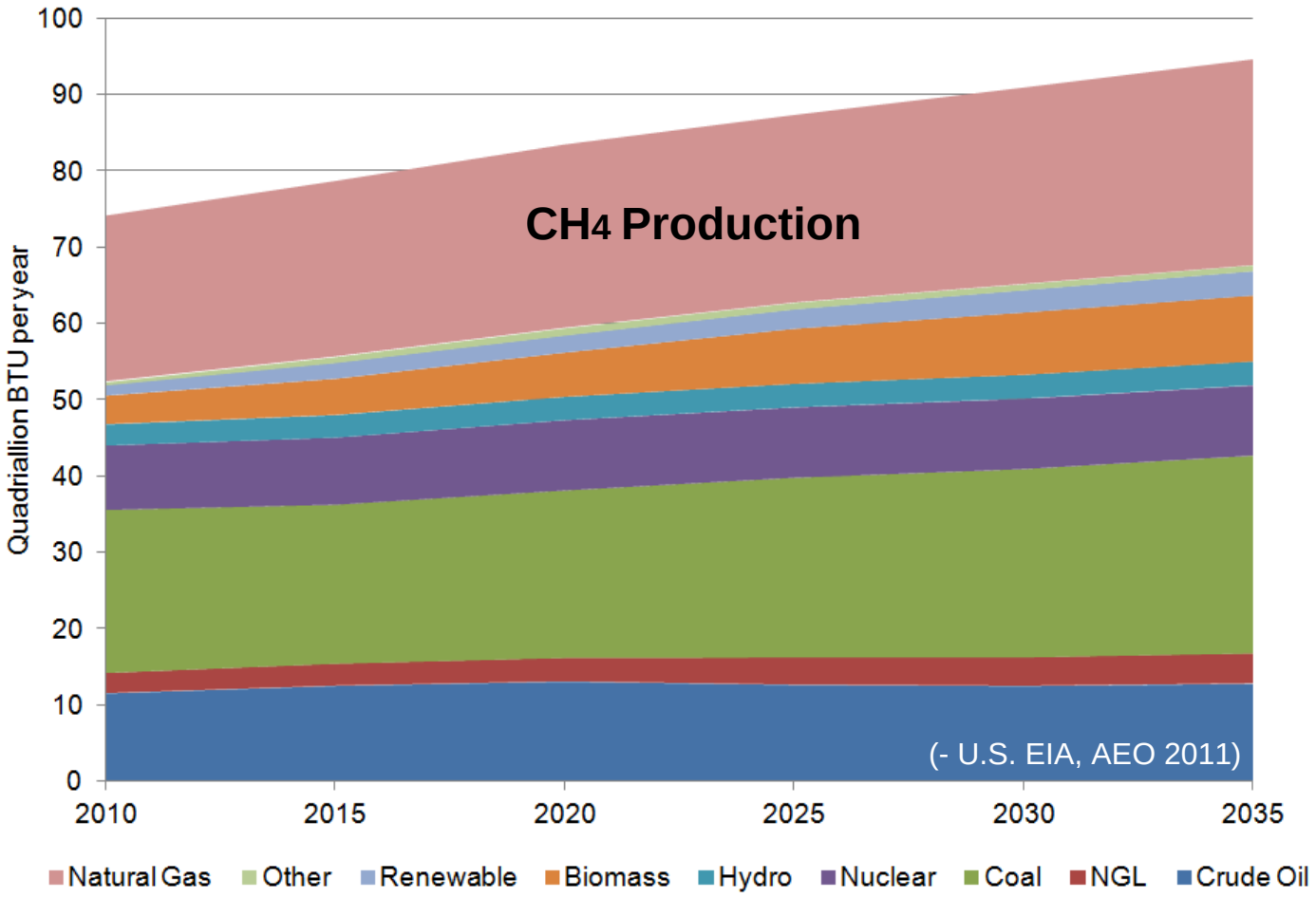
  All CH_4 sources in the U.S.

  - 1,700 Bcf / yr or 31.8 Mtonnes/yr

- **In CO_2 equivalent terms:**
  - 19 Tg or 0.3% of GWP (100 yrs)
  - 50 Tg or 0.6% of GWP (20 yrs)
- **Revenue loss (1 MCF~1 mmBTU, $4/mmBTU):**
  - ~$200 M / yr
- **Fraction of annual nat gas demand:**
  - Annual ~21 Tcf/yr
  - 48 Bcf / 21 Tcf ~ 0.2%

(- GHG emissions, EPA 2010
- Technical note on the 1990 – 2009 inventory estimates for natural gas systems)

Projected U.S. CH_4 Emissions from Unconventional Well Completions



- Use values from the previous slide ***and*** apply the same percentage growth of 0.9% yoy production growth ***and*** attribute all growth to unconventional gas production:
  - 1.1 Mtonnes/yr of CH_4
  - 24 Tg CO_2 equivalent (100 yr) or 63 Tg CO_2 equivalent (20 yr)
  - 60 Bcf/yr or ~$240 M/yr (1 MCF ~ 1 mmBTU, $4/mmBTU)

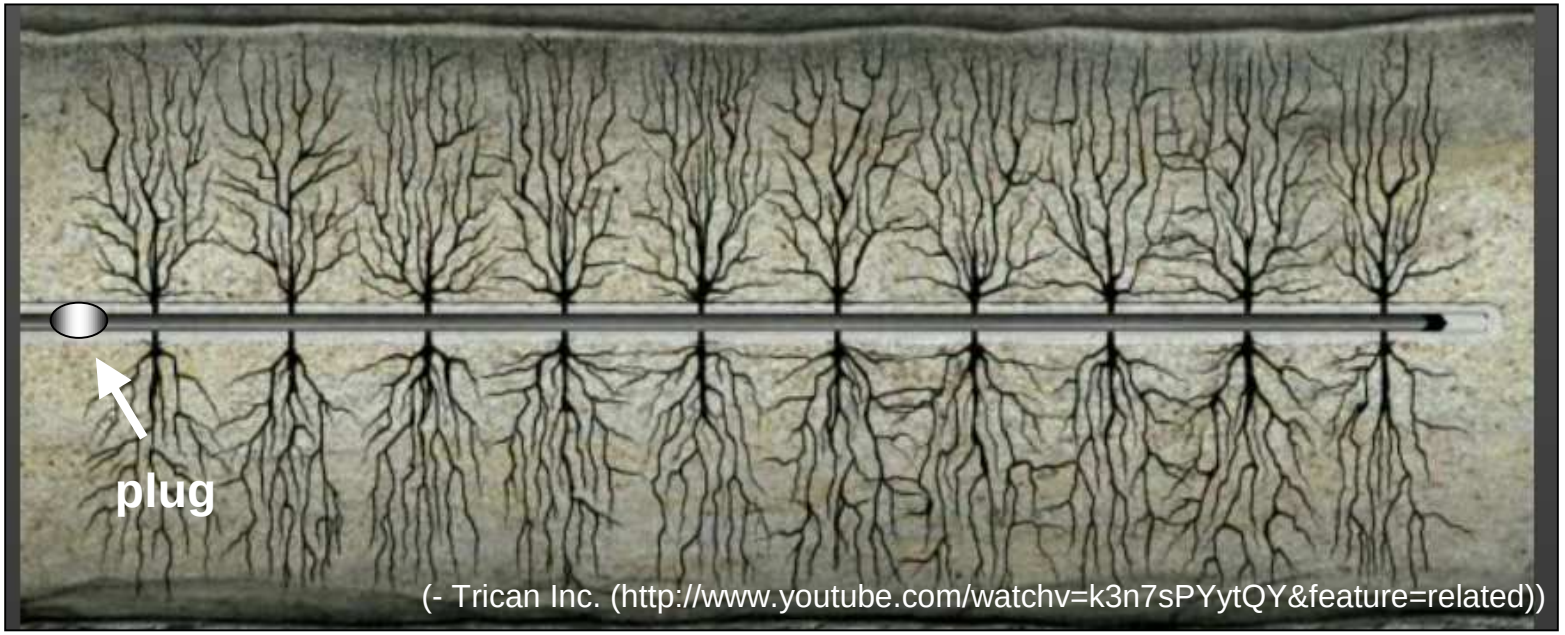
Reducing Impacts of CH_4 from Unconventional Gas Production

- Lowest hanging fruit is regulation of well completion practices.
- Pipeline leakage = hard to detect and survey, costly to excavate and fix.
- Equipment leakage = small locations from many locations, accounting problems.
- Impact may be low, but if it is easy to fix, why not?

Outline

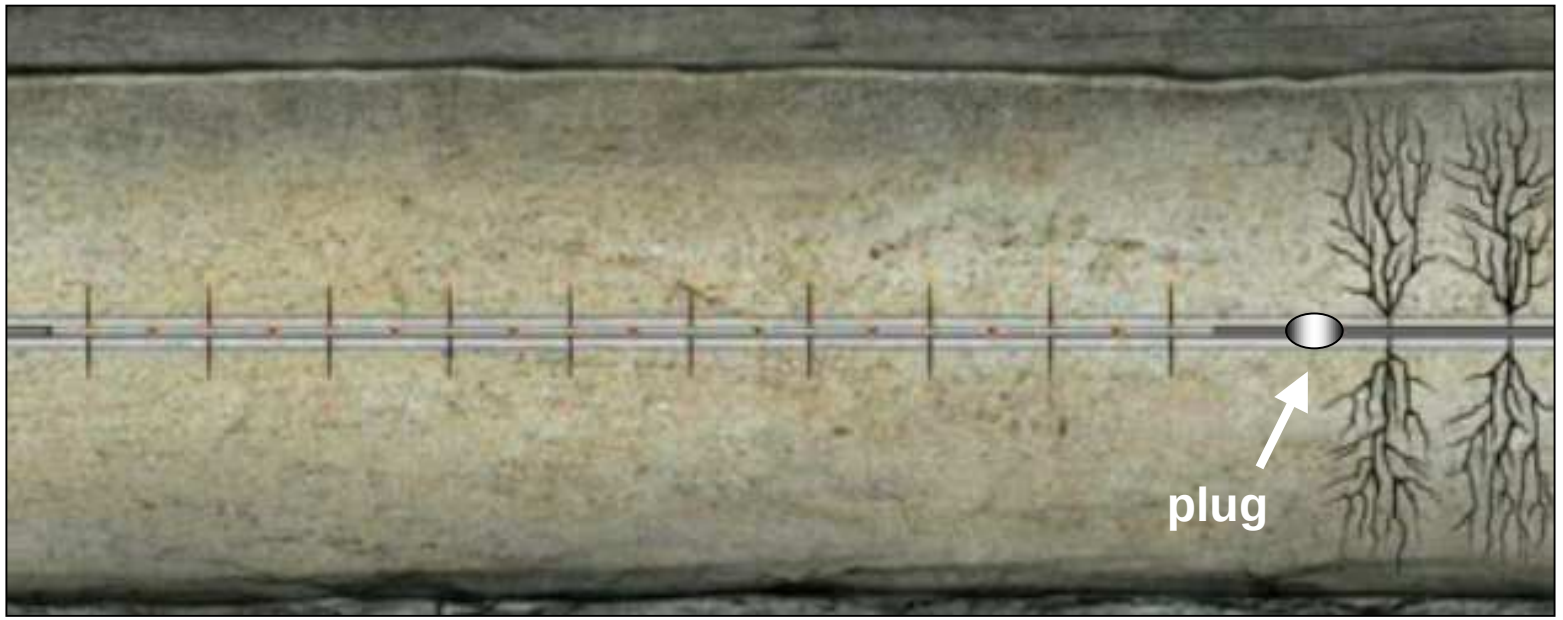
- When do emissions occur?
- What is a green completion?
- What technology is available?
  - BP, Williams
  - Questor
- Why is it sometimes difficult implement green completions?
  - High pressure
  - Low pressure
  - Lack of infrastructure
  - High impurity concentrations
- Academic opportunities
  - Enhanced recovery through well stimulation
  - Reservoir characterization and modeling

CH_4 Emission Source: Fluid Flow-Back During Fracking



- Well is drilled, fracked using water, proppant (sand), chemicals.
- The frack fluid is allowed flow-back under reservoir pressures, along with CH_4 (both free and dissolved), typically into an open pit.
- Sometimes additional fluids are injected to clean out the well bore after each fracking stage.
- Well is shut in, and a plug is set to isolate stage 1.
- After stage 1 is isolated, stage 2 (closer to well head) is fracked.
- This is repeated for 5 to 6 stages (approx. 1,000 ft per stage).

CH_4 Emission Source: Drill Out of Plugs



- After all stages are fracked, isolation plugs are drilled out.
- Different isolation techniques exist in the industry, but concept is the same, and all techniques require drill out.
- Gases migrate up the well bore as plugs are drilled out.

CH_4 Emission Source: Well Clean Up

- Fluid is cleaned out of well-bores using additional gas.
- Pump-jacks can be used to remove fluid, but relatively high in cost and fluid removal may be incomplete.
- Well bore must become liquid-free as quickly as possible.
- Well blow down is also used in mature conventional wells with low reservoir pressures to remove water columns.

(- Reduced emission (green) completion in low energy reservoirs, BP America Production Company, 2008)

Green Completions: EPA Ruling

- Green completions are mandatory starting January 1, 2015. Until then, all production gases must be flared.
- CO, WY already require green completions.
- Operators in CO can override standards for safety reasons. In case CH_4 cannot be captured, produced gases must be flared.

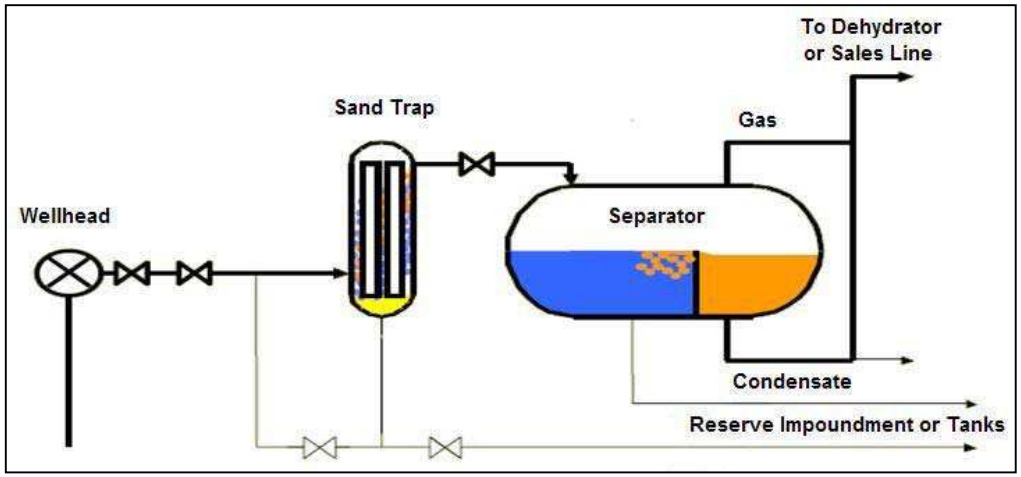
(- EPA's Air Rules for the Oil&Natural Gas Industry: Summary of key changes to the new source performance standards

- http://www.bloomberg.com/news/2012-04-17/drillers-say-costs-manageable-from-pending-gas-emissions-rule.html

- http://www.epa.gov/airquality/oilandgas/pdfs/20120417changes.pdf

- COGCC)

Green Completions: CH_4 Capture



(- EPA: Reduced Emissions Completions)

(- Devon Energy)

"Green completion techniques are methods that minimize the amount of natural gas and oil vapors that are released to the environment when a well is being flowed during the completion phase of a well." (COGCC)

Green Completion Technologies in the Industry

- Under suitable reservoir conditions, technology exists to capture CH_4 for sales:
  - BP
  - Weatherford
  - Devon
- Questor (for flaring)
- Appropriate tech and properly sized surface units must be deployed for given reservoir conditions.

Green Completion Challenges: High Pressures

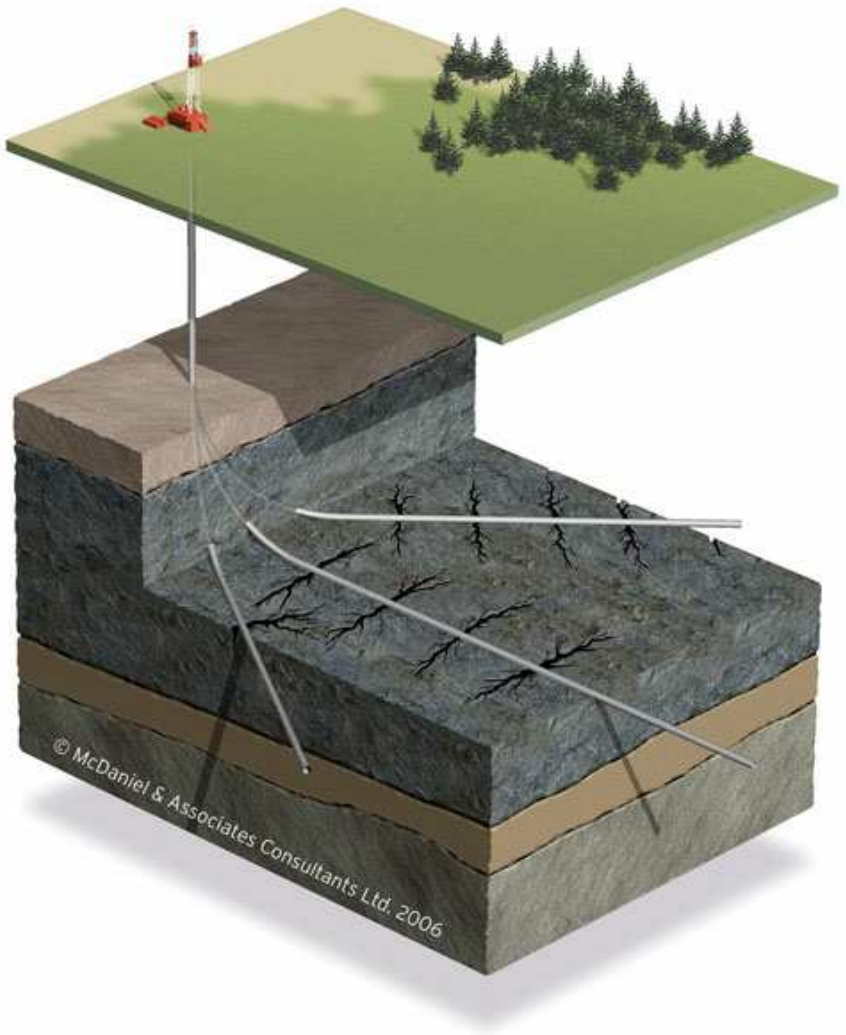
- Flow back unit leading to high back pressure build up, impeding flow-back.
- If fluid is not discharged as quickly as possible, well “damage” can occur.
- Surface equipment requires additional pipe and equipment with various fittings and bends:
  - High pressure may lead to wash outs (compare to simple venting to open pits)
  - Workers are exposed to additional risks

(- Reducing methane emissions during completion operations, 2007 Natural Gas STAR Production Technology Transfer Workshop)

Green Completion Challenges: Low Energy Reservoirs

- Low pressure reservoirs may not allow frack water flow-backs against back pressures.
- Air clean out preferred over liquid clean out due to low reservoir pressure – separation of gases are costly, especially at lower pressures.
- EPA has identified and exempted roughly 10% of unconventional natural gas wells from green completion standards.

(- EPA ruling changes 2012)



Green Completion Challenges: Wildcat wells (No Sales Line)

- Wildcat wells do not have pipelines near by into which gases can be unloaded.
- Many unconventional plays (shale, tight sand, tight coal) are wildcats that turn into production wells.
- Attributes of a wildcat well must be carefully defined.

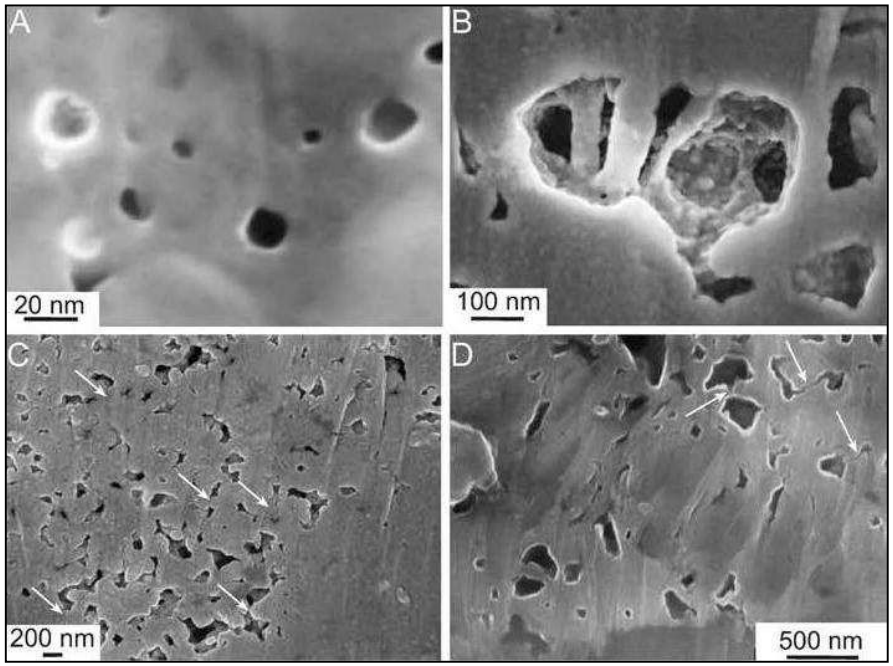
Green Completion Challenges: Impurities

(- Questor Inc.)

- Impurities (CO_2, N_2, moisture, and other VOCs) in production gases must be separated prior to CH_4 capture.
- Separation units and dehydration units can be costly.
- There may be flow-back gases from which CH_4 cannot be separated and are also hard to flare.
- Companies like Questor, who specialize in combusting impure gases could play an important role.

Academic opportunities

- In the absence of CH_4 capture and flaring, the next best solution is drilling less wells.
- Academic opportunities:
  - Develop understanding of flow physics and subsurface to better estimate decline curves
  - Improve reservoir characterization / simulation techniques in order for optimal well placement and orientation through target
  - Engineer enhanced oil / gas recovery methods



Conclusions

- CH_4 impact from unconventional natural gas well completions are relatively small in comparison to other GHG emission sources in the U.S.
- CH_4 emitted annually during unconventional well completion accounts for 3% of all yearly CH_4 emissions in the U.S.
- CH_4 emissions during an unconventional well completion occur during:
  - Frack fluid flow-back
  - Drill out of plugs
  - Clean out, blow down of well bore
- Cost effective industry solution is readily available under appropriate reservoir conditions.
- Implementation challenges of green completions remain:
  - High pressure= surface risks, pressure build up
  - Low pressure = slow fluid flow back + costly capture
  - Wildcat wells = lack of pipeline for capture
  - High impurities = costly to capture and maybe hard to flare
- Next best after CH_4 capture is flaring (e.g. Questor) or minimizing number of wells drilled in the first place (academic).