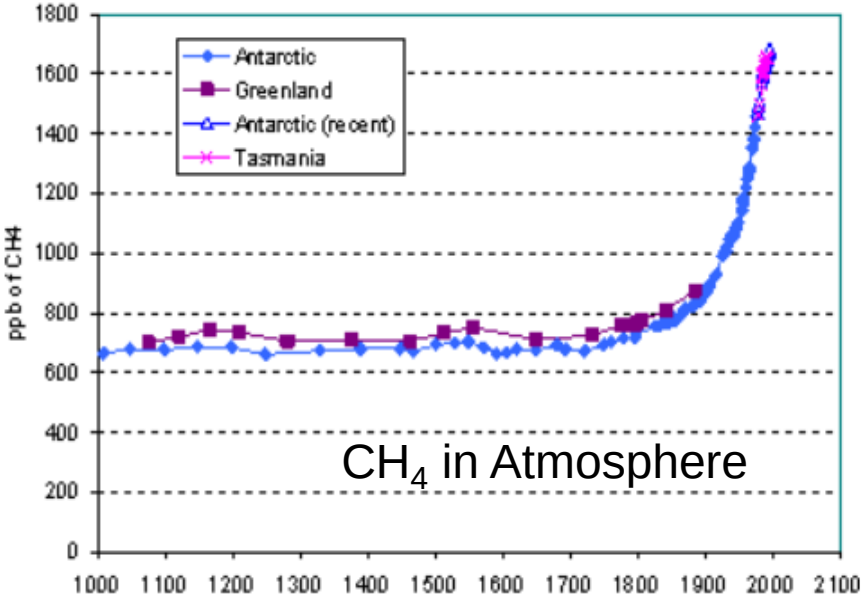




# Shale Gas Development: Leaks and Vents

**A. R. Ingraffea**

***Dwight C. Baum Professor***
***Cornell University***
***and***
***Physicians, Scientists, and Engineers for Healthy Energy, Inc.***

***Northwestern University***
***April 18, 2013***

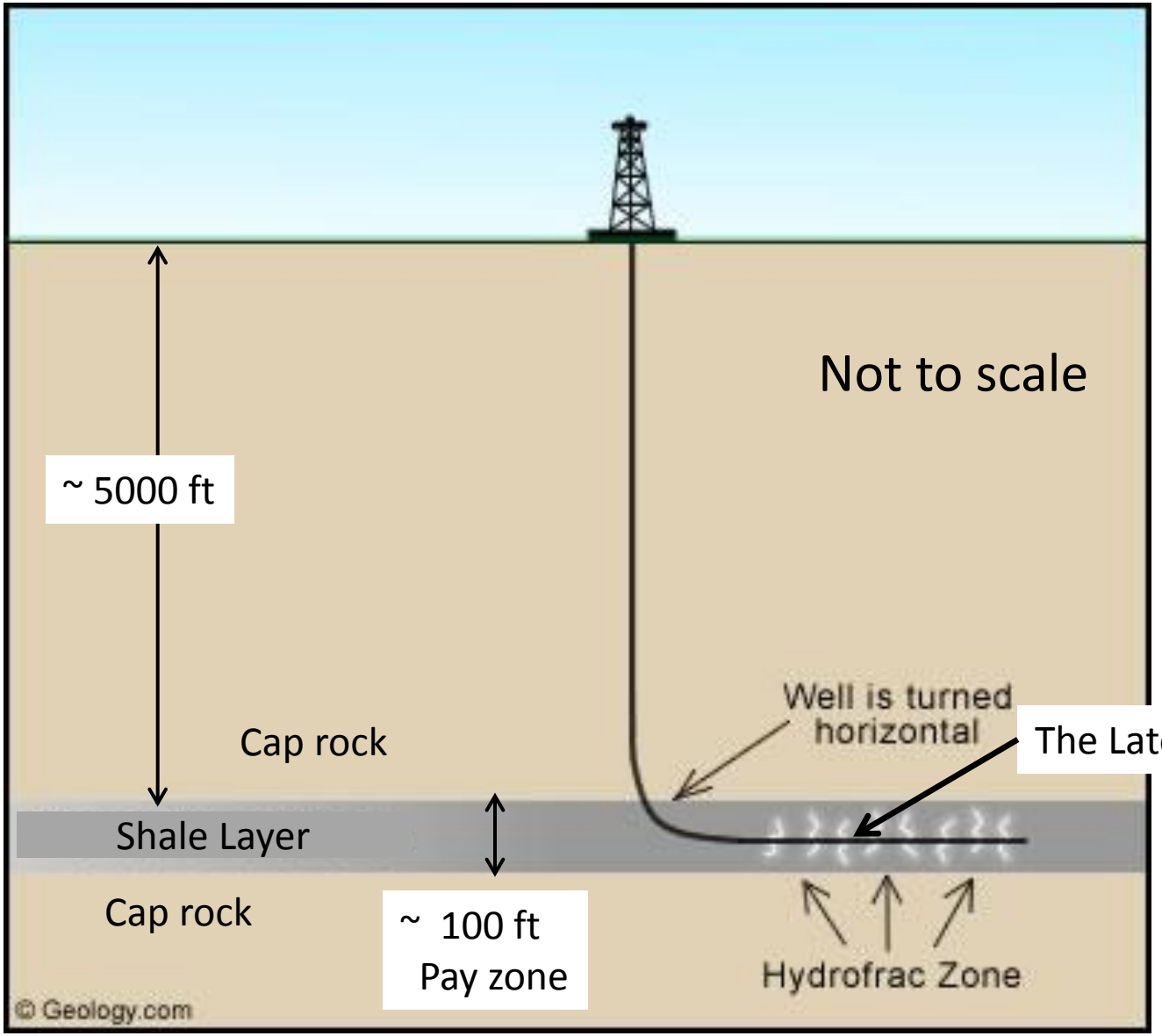
# Outline of Presentation

- **Geology Rules!: What Is Unconventional Development of Methane/Oil from Clustered, Multi-well Pads Via High-Volume Frac'ing from Long Laterals?**
- The Fluid Migration Problem: Why and How Often Do Wells Leak?
- The Methane Emission Problem: Where, When?
- Is Shale Gas a Clean Fossil Fuel?

# Why Is Shale Gas Development "Unconventional"?

- Because it requires 4 technologies only recently combined to make gas production from impermeable shales technically and economically feasible.
- Directional drilling: needed to access a thin layer of shale with long laterals.
- High frac fluid volumes: needed to stimulate gas release from many existing fractures.
- Slickwater: needed to control the amount of power needed to pump large volumes of frac fluids, at high pressures, quickly, over long distances, through small diameter casing.
- Multi-well Pads and Cluster Drilling: needed to access as much of the gas inventory as possible, under constraints of leasing and capital.

# High Volume, Slickwater Fracing from Long Laterals: The Concept



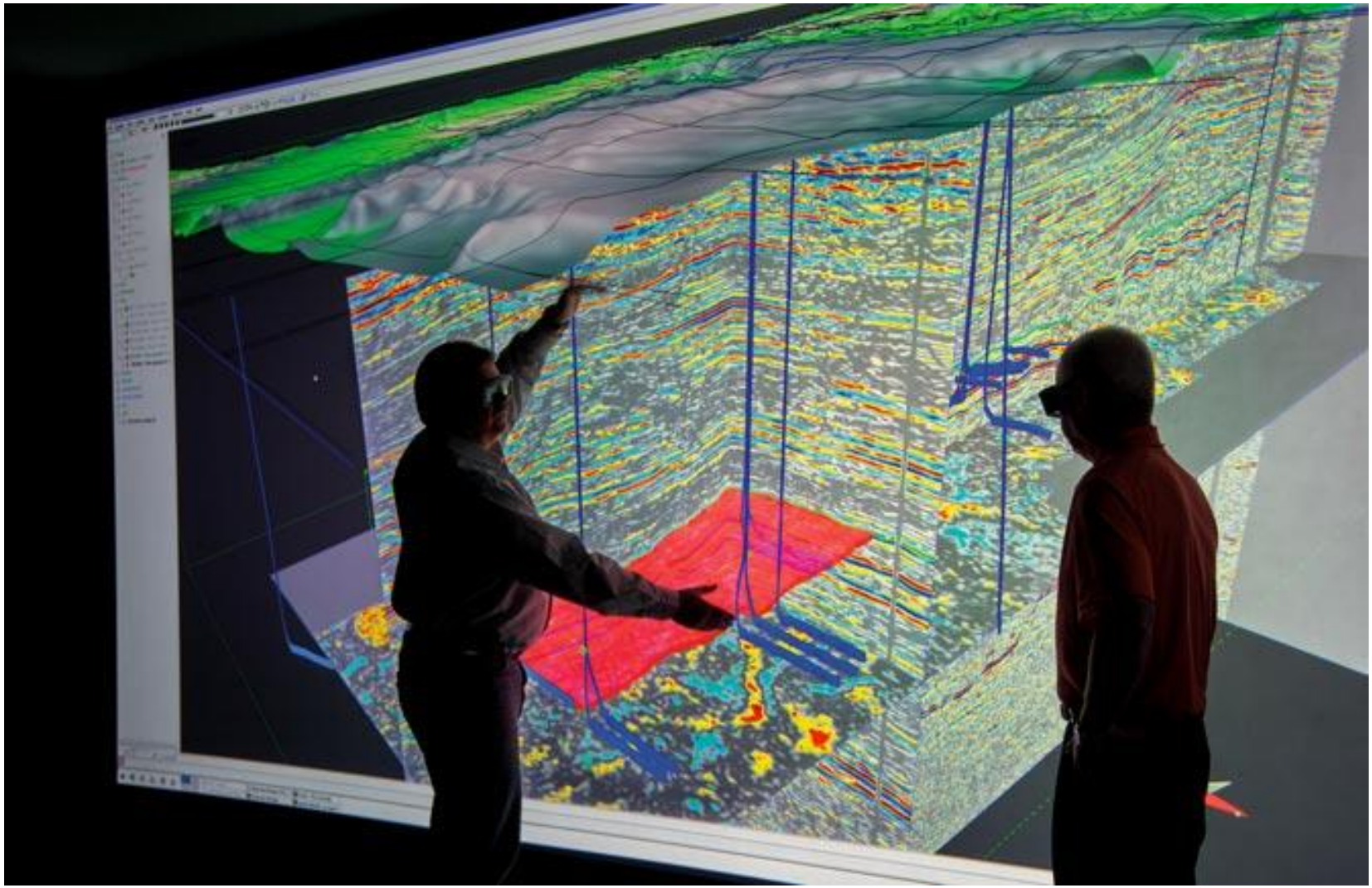
# Gas Producing Shales are Heavily Fractured Naturally

**Geneseo-Burket (Devonian black shale)**

Taughannock Falls State Park, Trumansburg, N.Y.

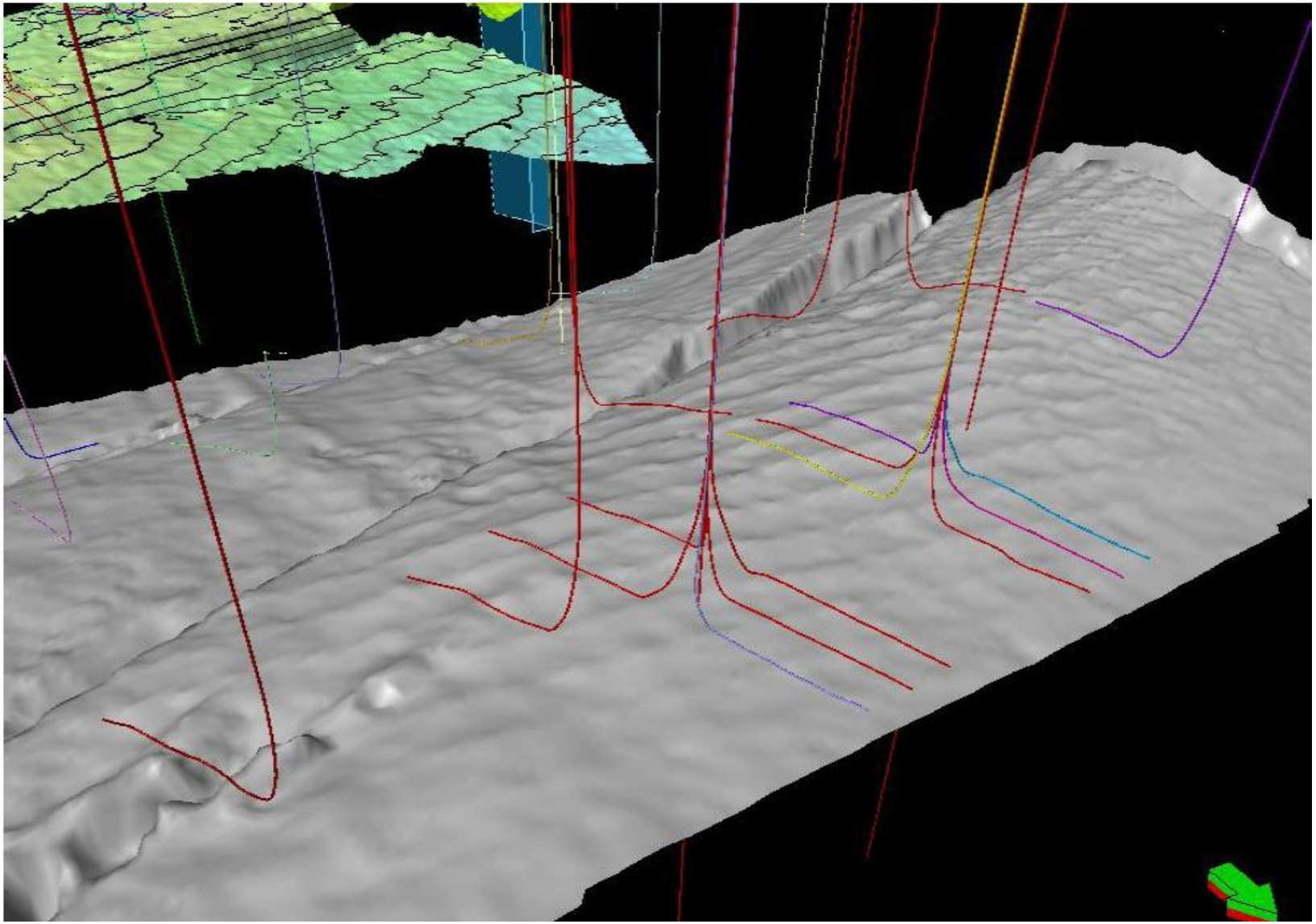
Photo Courtesy T. Engelder

# 3D Imaging of the Sub-Surface



From *National Geographic*, December 2012

# Targeting the Shale Layer Via Multiple, “Horizontal” Wells from Clusters of Pads



From Cody Teff, Shell Appalachia, WELL CONSTRUCTION PRACTICES IN THE MARCELLUS

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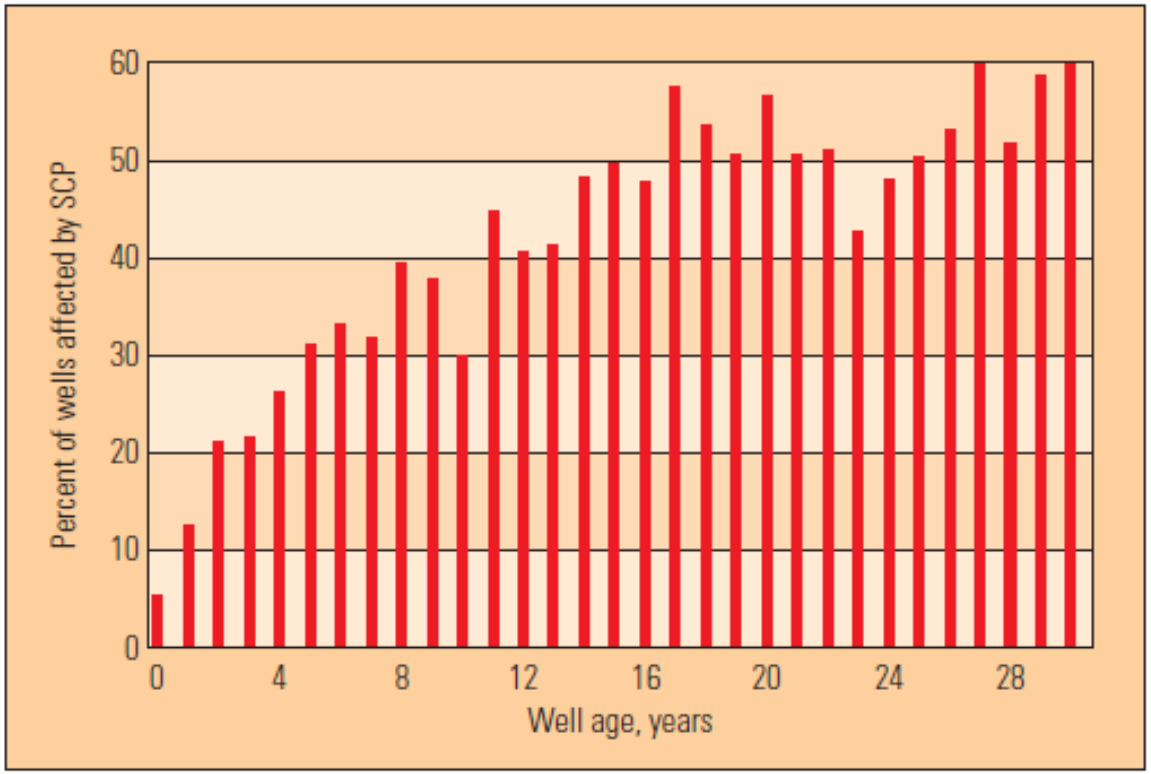
# Leaks and Vents: Impact on Drinking Water

VIDEO of
Methane Bubbling
At Head of Leaking Well

# Industry-Reported Data On Loss of Wellbore Integrity: Offshore Wells



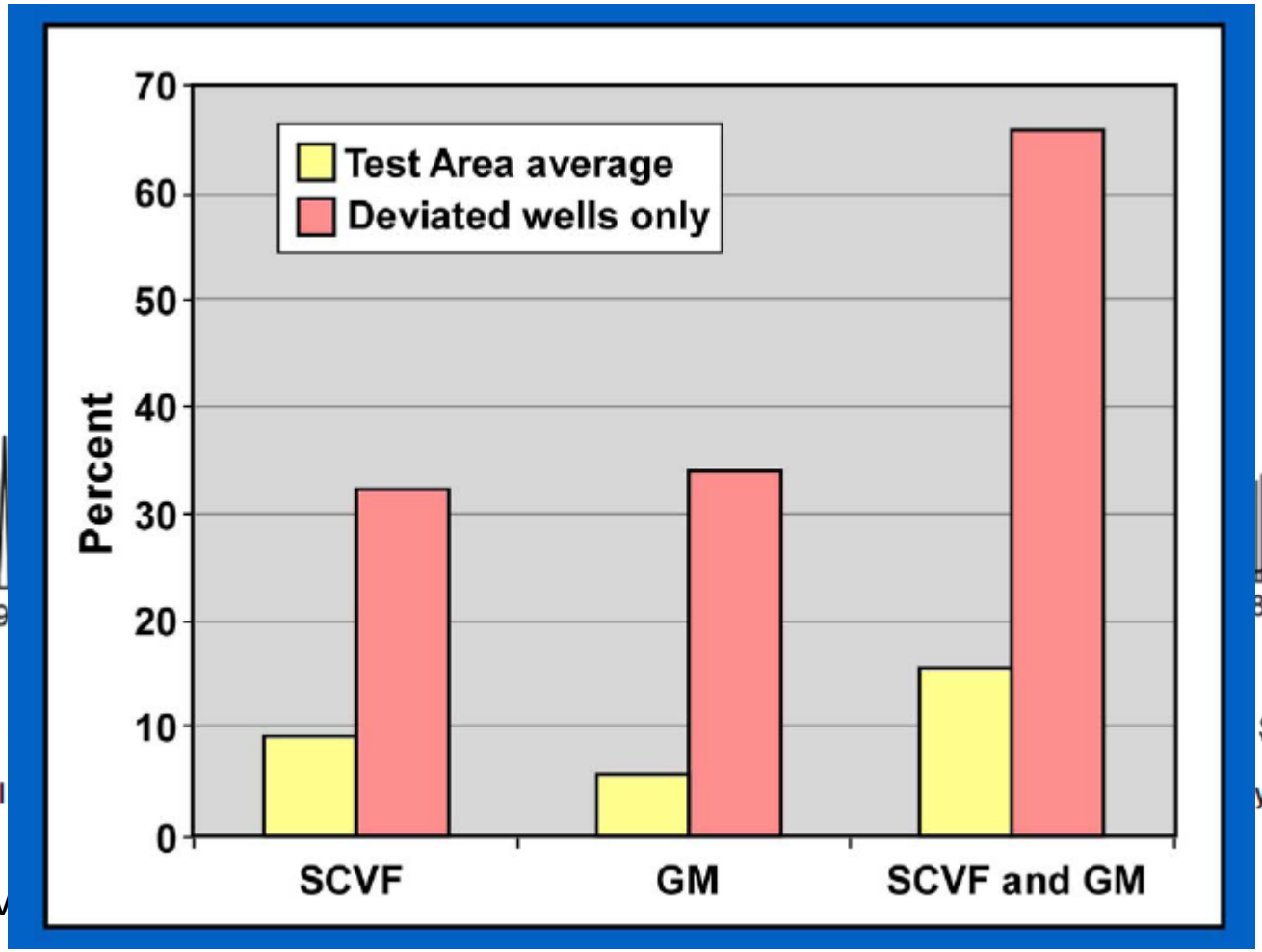

^ Wells with SCP by age. Statistics from the United States Mineral Management Service (MMS) show the percentage of wells with SCP for wells in the outer continental shelf (OCS) area of the Gulf of Mexico, grouped by age of the wells. These data do not include wells in state waters or land locations.

SCP=Sustained Casing Pressure. Also called sustained annular pressure, in one or more of the casing annuli.

- About 5% of wells fail soon
- More fail with age
- Most fail by maturity

Brufatto *et al.*, *Oilfield Review*, Schlumberger, Autumn, 2003

# Industry-Reported Data On Loss of Wellbore Integrity: Onshore Wells




Watson and Bachu, SPE 106817, 2009.

# Industry well integrity outlook

- Industry will drill more wells in next decade then have been drilled in last 100 years
- Global well population is +/- 1.8 million, of which +/- 35 % has sustained casing pressure
- Public awareness and concern of zonal isolation requirements is increasing ( USA / Australia / Europe )
- Geothermal wells and CO2 sequestration wells are on the increase
- Subsidence is a risk in some depleting reservoirs
  Life cycle extension of aging assets is becoming a pre-requisite of legislators
- Zonal isolation challenges and assurance does need push in technology
- Abandonment of legacy wells is becoming more of a focus
- Industry collaboration is an inevitable pre-requisite on all topics

# Some Mechanisms of Gas Migration

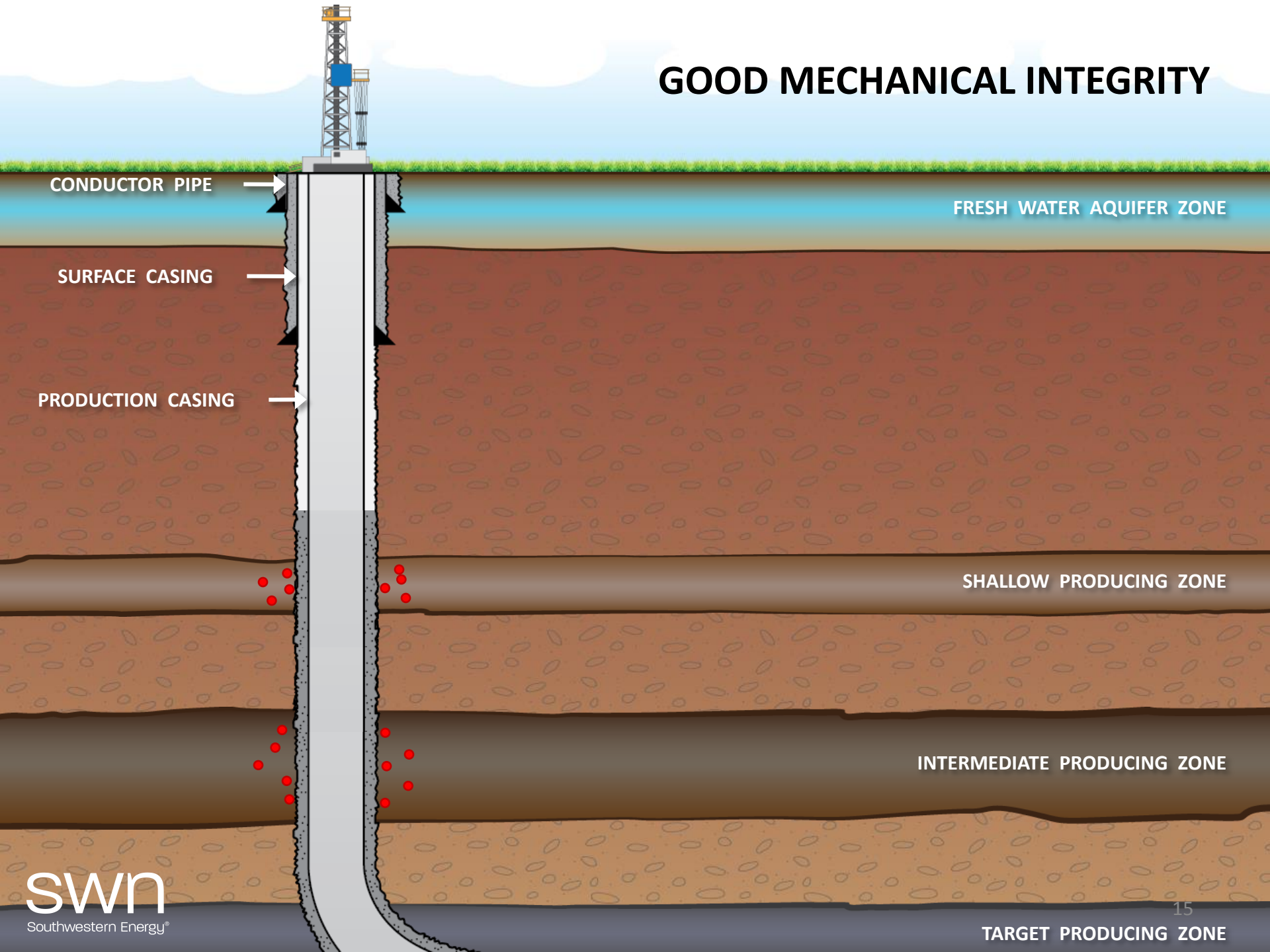
- Gas Migration Through Cement: percolation during curing
- Cement Sheath Failure: high temp, high pressure, perforation
- Improper Cement Design and Placement: poor chemistry, poor mud cleanup, low cement top
- Casing Failure: Corrosion, joint failure, fracture
- Cross Flow Between Adjacent Wells

From Watson, **PAPER 2004-297**Petroleum Society's 5th Canadian International Petroleum Conference


Figure 4: Incomplete displacement of drilling mud and resulting cement and drilling fluid channels. Over time, the gels in the drilling fluid well shrink, forming a gas flow path in the annulus.[3]

From Watson, **PAPER 2004-297**Petroleum Society's 5th Canadian International Petroleum Conference

# GOOD MECHANICAL INTEGRITY

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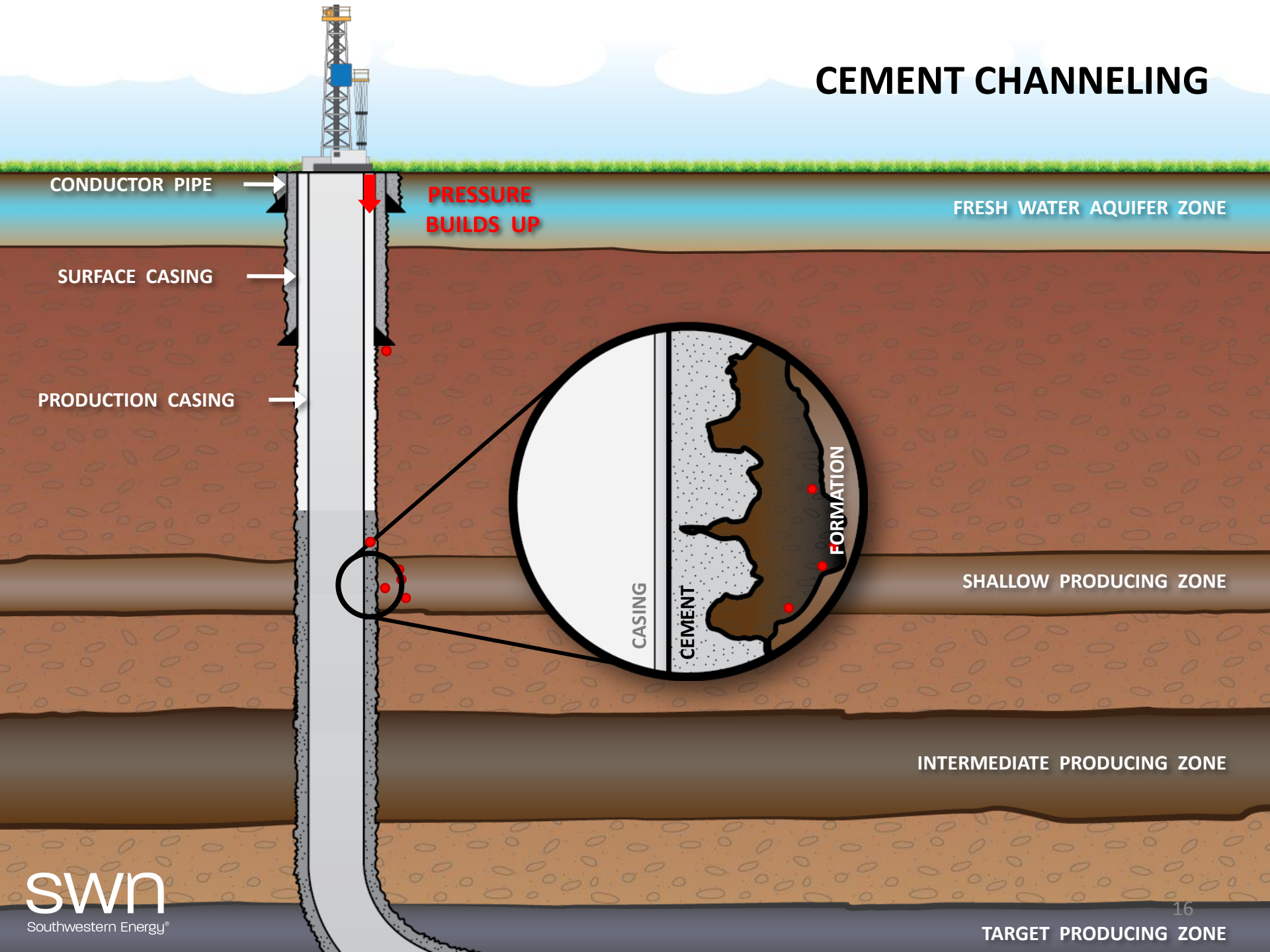
# CEMENT CHANNELING

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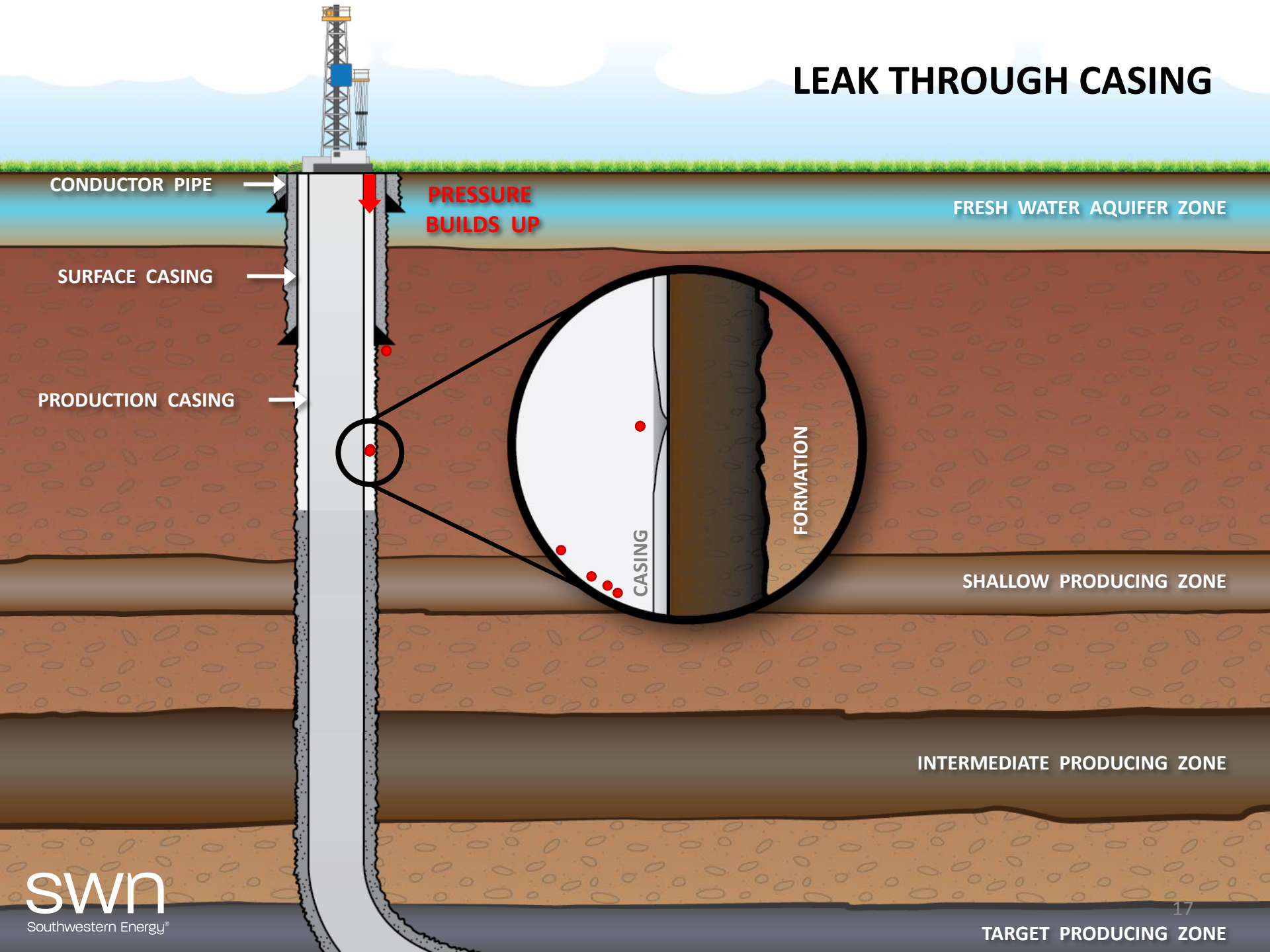
# LEAK THROUGH CASING

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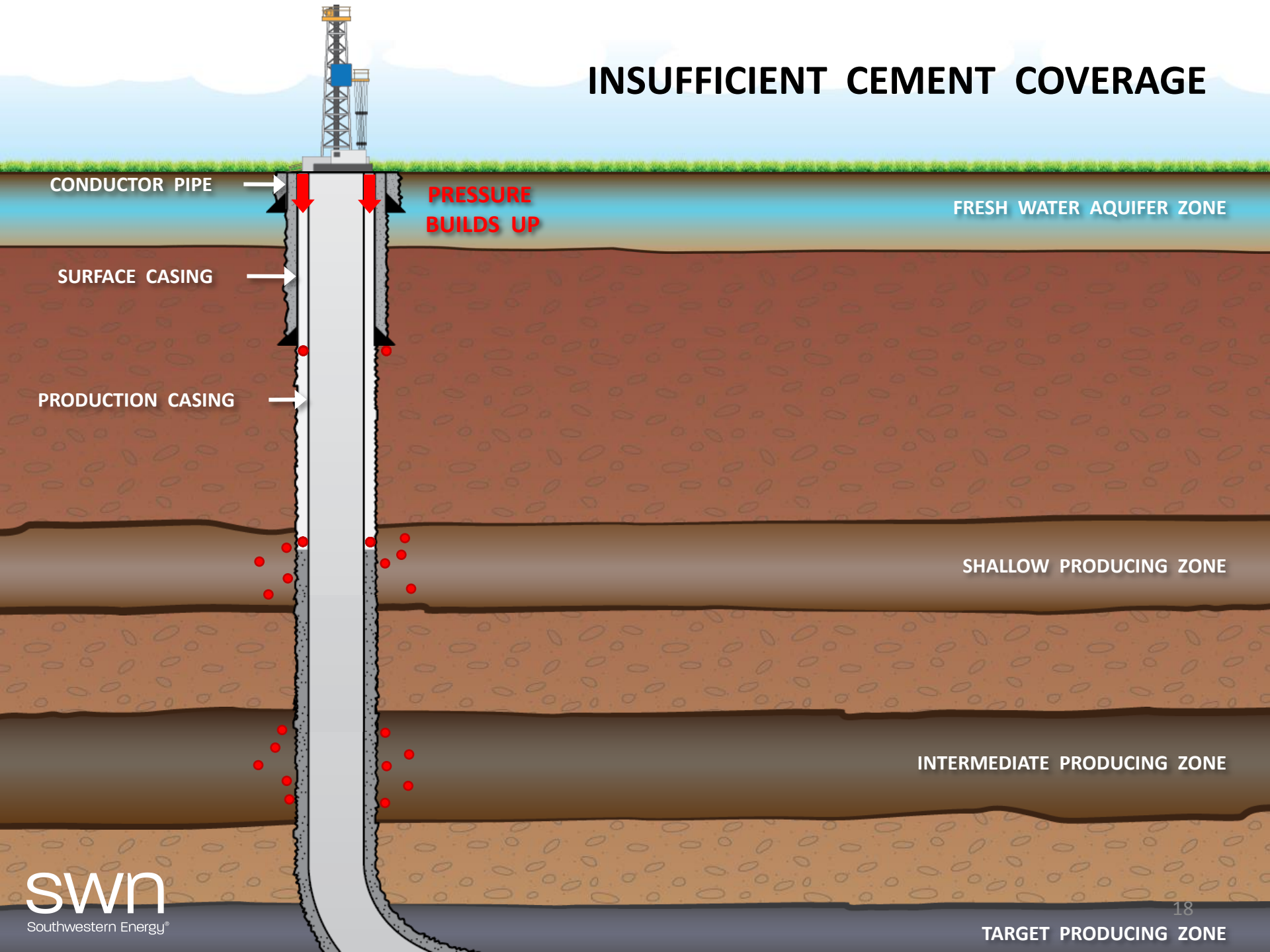
# INSUFFICIENT CEMENT COVERAGE

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# Recent Operator Performance in the Pennsylvania Marcellus Play: Protocol

- Access Pennsylvania Department of Environmental Protection Violations Database online.

- First Pass: Count wells with violations for “leak” codes; eliminate duplicate wells in database.

- Second Pass: Count wells with leakage noted via inspection *but which had not been issued violations.*

- Divide total number of wells found leaking per year by number of wells drilled that year.

# Recent Operator Performance in the Pennsylvania Marcellus Play: Results of Survey

1,609 wells drilled in 2010.
97 well failures.
6% rate of failure.

200,000 Marcellus Wells Expected
You do the math….

1,346 wells drilled in 2012
120 well failures.
8.9% rate of failure.

Consistent with previous industry data, and not improving.

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# Methane Can Be Purposely Vented and Accidently Leaked, Upstream/Midstream/Downstream

- During drilling
- During initial frac fluid flow-back period
- Routinely and continuously at the well site
- During liquid unloading
- During gas processing
- During transmission, storage, and distribution

# Upstream Example: Gas Is Supposed to Rise Inside the Production Casing, Not Outside

VIDEO of
Methane Bubbling
At Well Head

# Upstream Example: Bubbling form Gas Migration in Muncy Creek, Lycoming County, PA:


Video Courtesy of Ralph Kisberg, Responsible Drilling Alliance

# Marcellus Well Being "Finished" Outside Dimock, Pa June, 2011: Major Source of Methane Emission


Photo and FLIR Methane-Tuned Video Courtesy Frank Finan

# Marcellus Well Being "Finished" Outside Dimock, Pa. June, 2011: Major Source of Methane Emission


Video

Video courtesy of Frank Finan

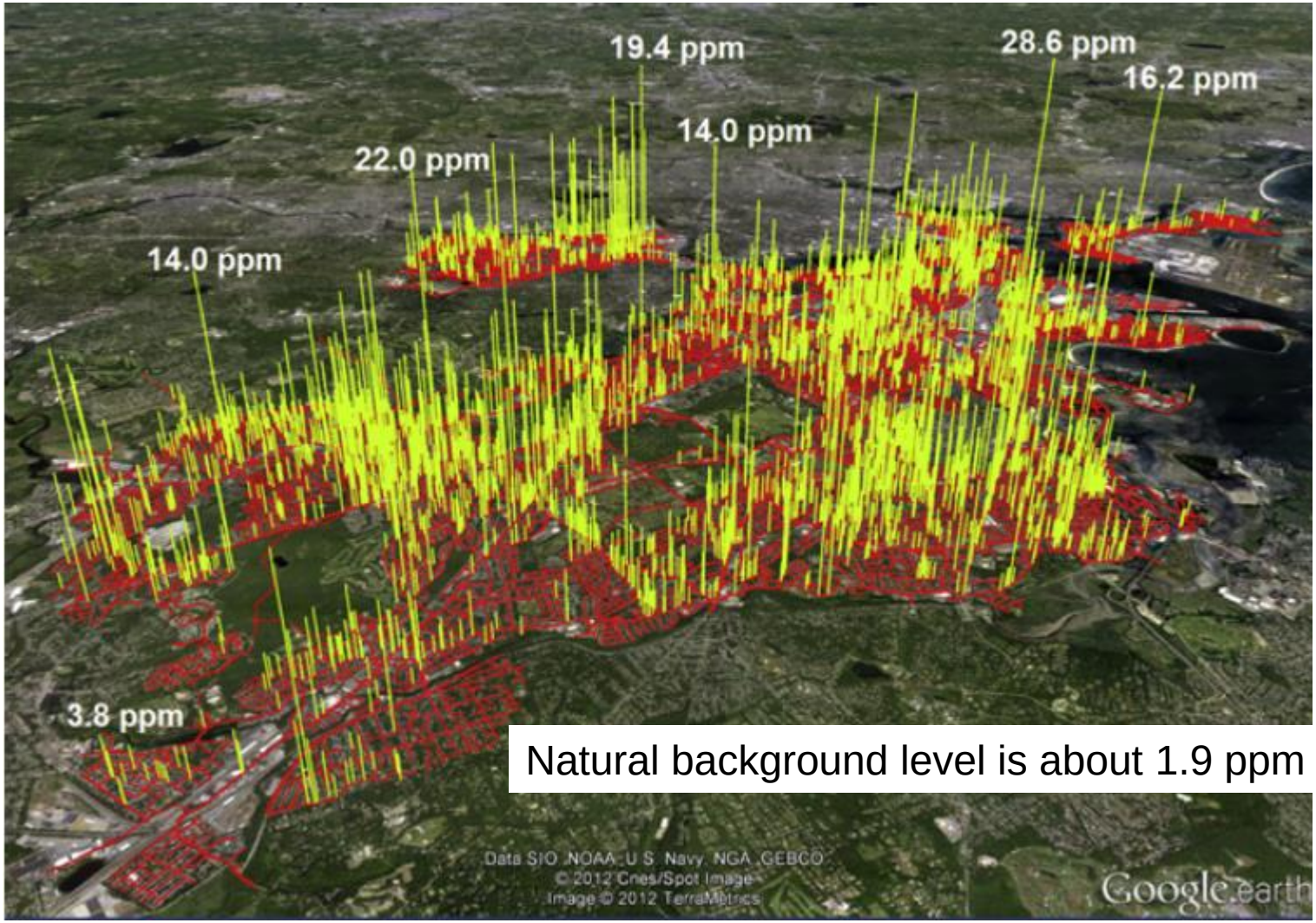
# Upstream+Midstream Methane Emission Measurements are Coming in Very High

Uinta Basin, Utah:
**Up to 9% of total production**
*Nature* 493, 12 (03 January 2013) doi:10.1038/493012a

Denver–Julesburg Basin, Colorado:
**2.3% to 7% of total production**
Pétron, G. *et al*. J. Geophys. Res. 117, D04304 (2012)

Note: Howarth, Santoro, Ingraffea predicted
**TOTAL (UPSTREAM+MIDSTREAM+DOWNSTREAM) emission range of 3.6% to 7.9%.**
*Climatic Change Letters*, 2011

# Downstream Methane Leakage from Aging Urban Distribution Pipelines: Boston MA




Natural background level is about 1.9 ppm

*N.G. Phillips et al. / Environmental Pollution 173 (2013) 1–4*

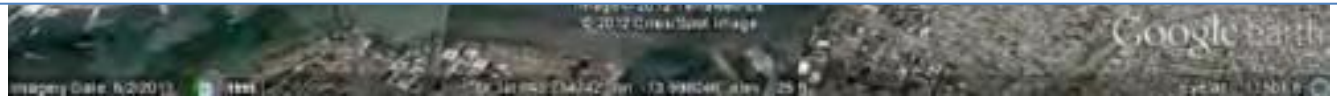
# Downstream Methane Leakage from Aging Urban Distribution Pipelines: New York City

Image 1. Results of methane survey of parts of Manhattan on 27 November 2012

" A **2.86%** leakage of all the natural gas handled by ConEd in Manhattan alone…"

"…8.6 billion cubic feet per year methane emissions from Manhattan…"

" Over 70% of the cast iron pipe in the ConEd system is over 100 years old, and almost all was installed before 1930, i.e., is more than 80 years old."




Payne and Ackley, Gas Safety Inc., 2013

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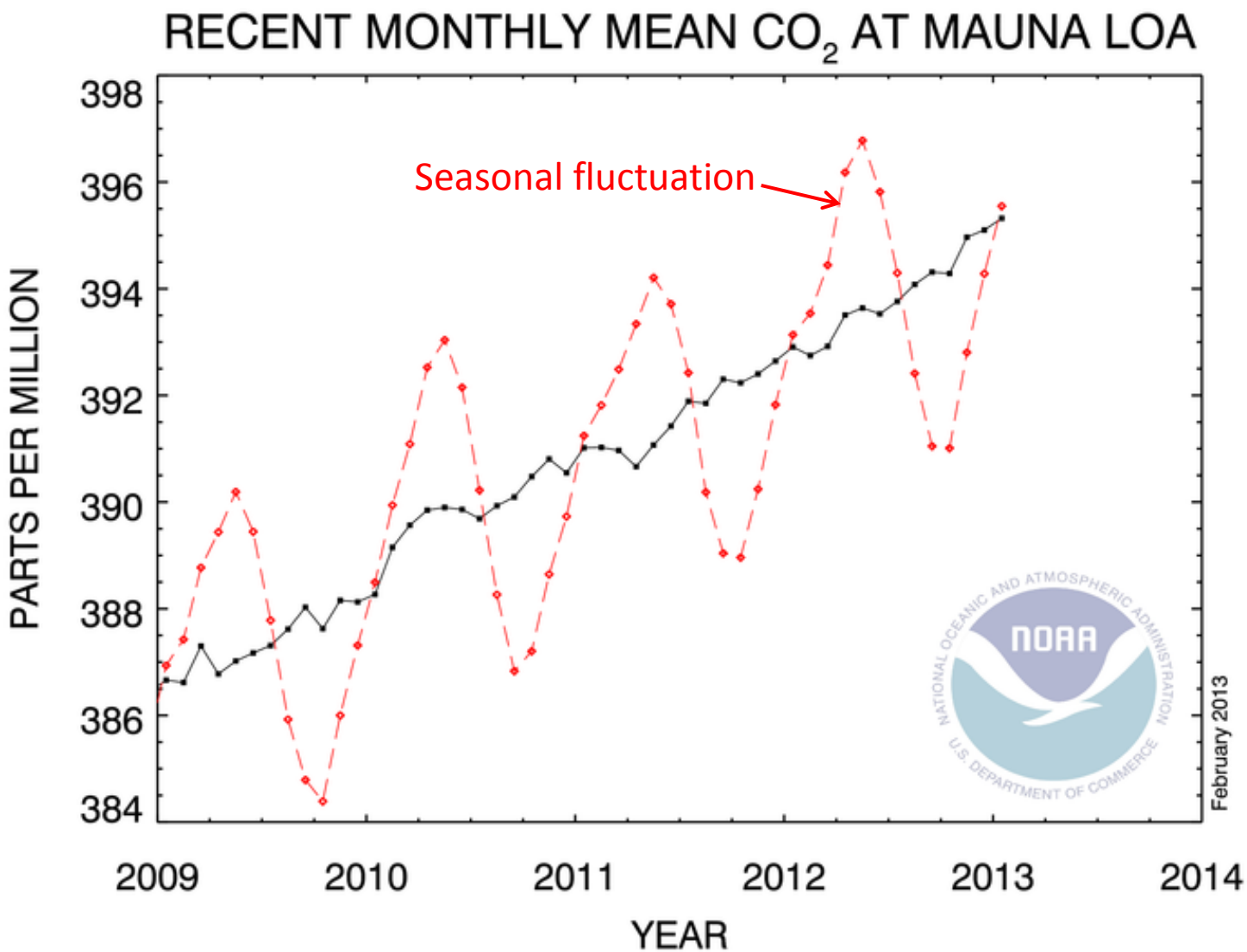
# $CO_2$ Concentration in the Atmosphere




http://www.esrl.noaa.gov/gmd/ccgg/trends/

# Methane Concentration in the Atmosphere: Historical Record

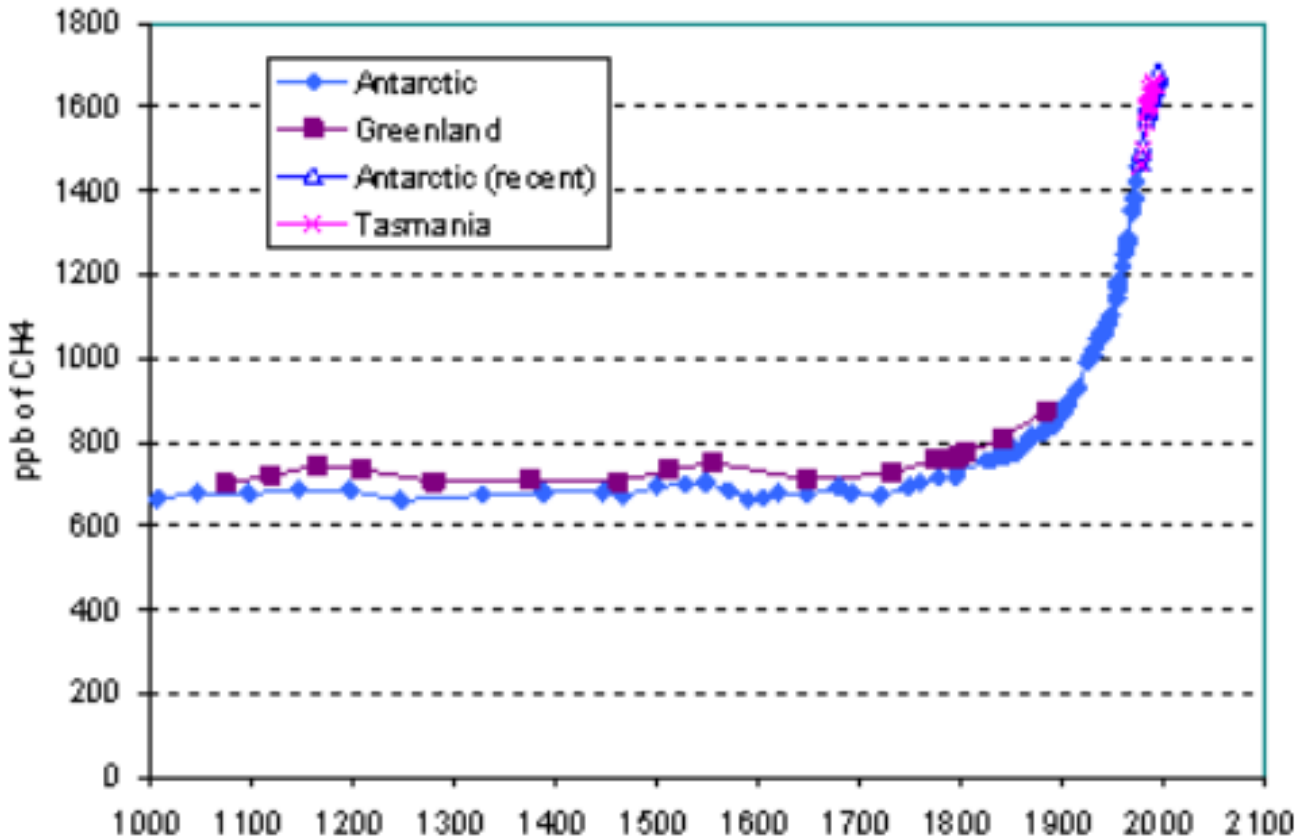
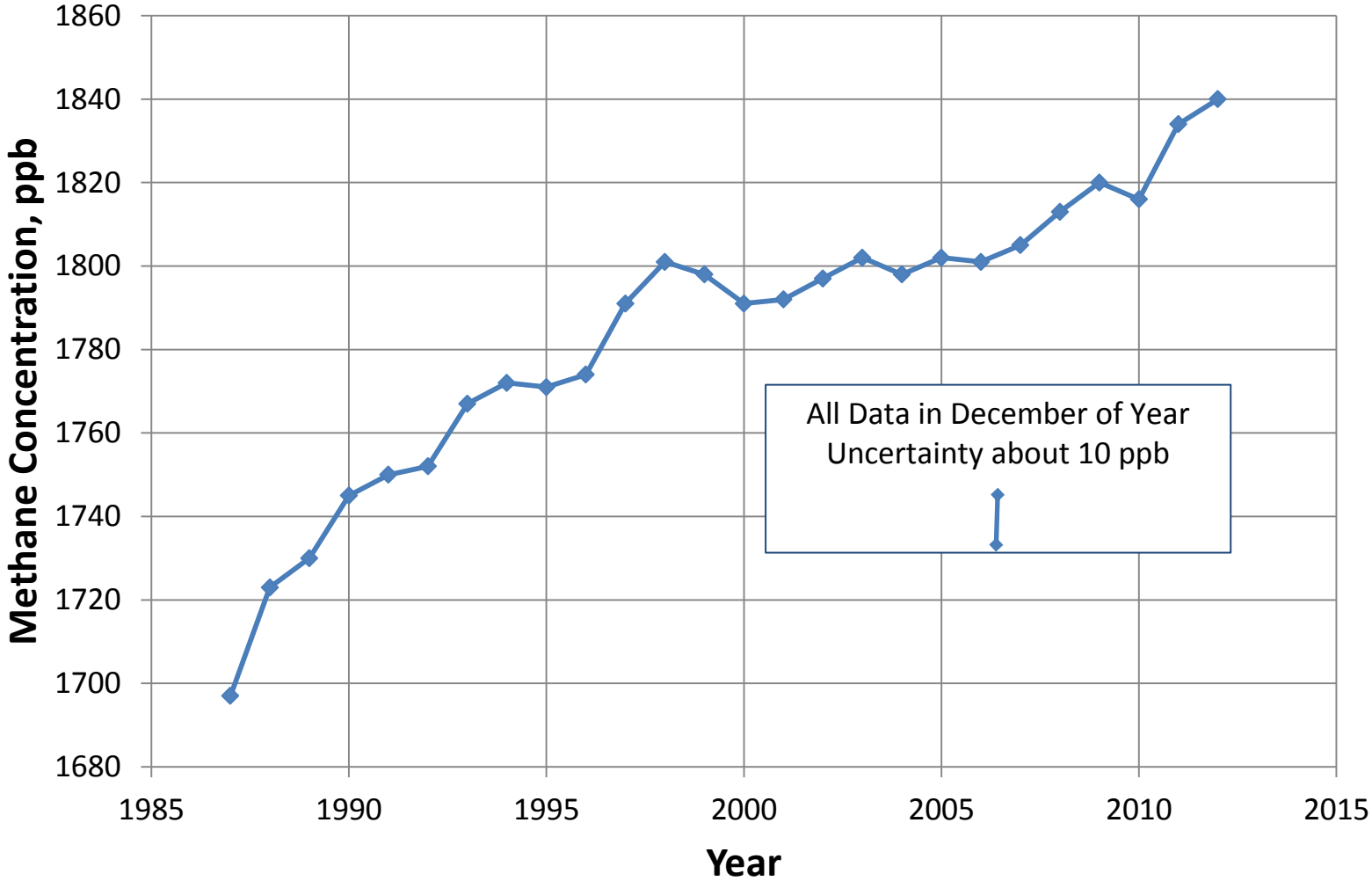



Figure 1: Methane content in the atmosphere obtained from measurements in glaciers in Antarctic and Greenland and in environmental samples collected in Tasmania.

http://www.ecen.com/eee55/eee55e/growth_of%20methane_concentration_in_atmosphere.htm

# Measured Methane Concentration in the Atmosphere: Recent Record



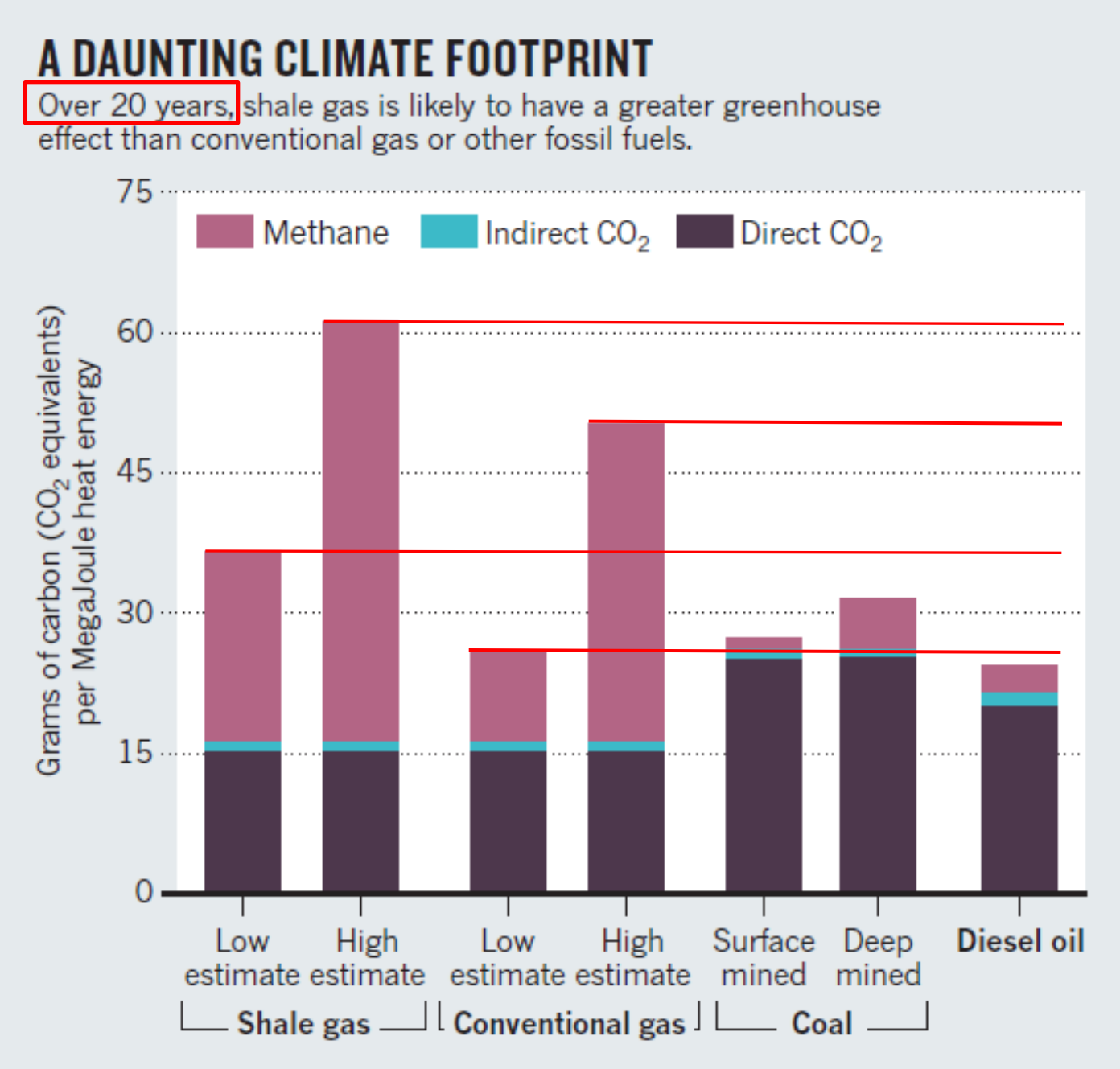

DATA FROM NOAA: http://www.esrl.noaa.gov/gmd/dv/iadv/graph.php?code=MLO&program=ccgg&type=ts

# Methane Is a Much More Potent Greenhouse Gas Than Carbon Dioxide

- Up to 33 times more potent over 100 years*
- Up to 105 times more potent over 20 years*
- Therefore, even small leakage rates important:

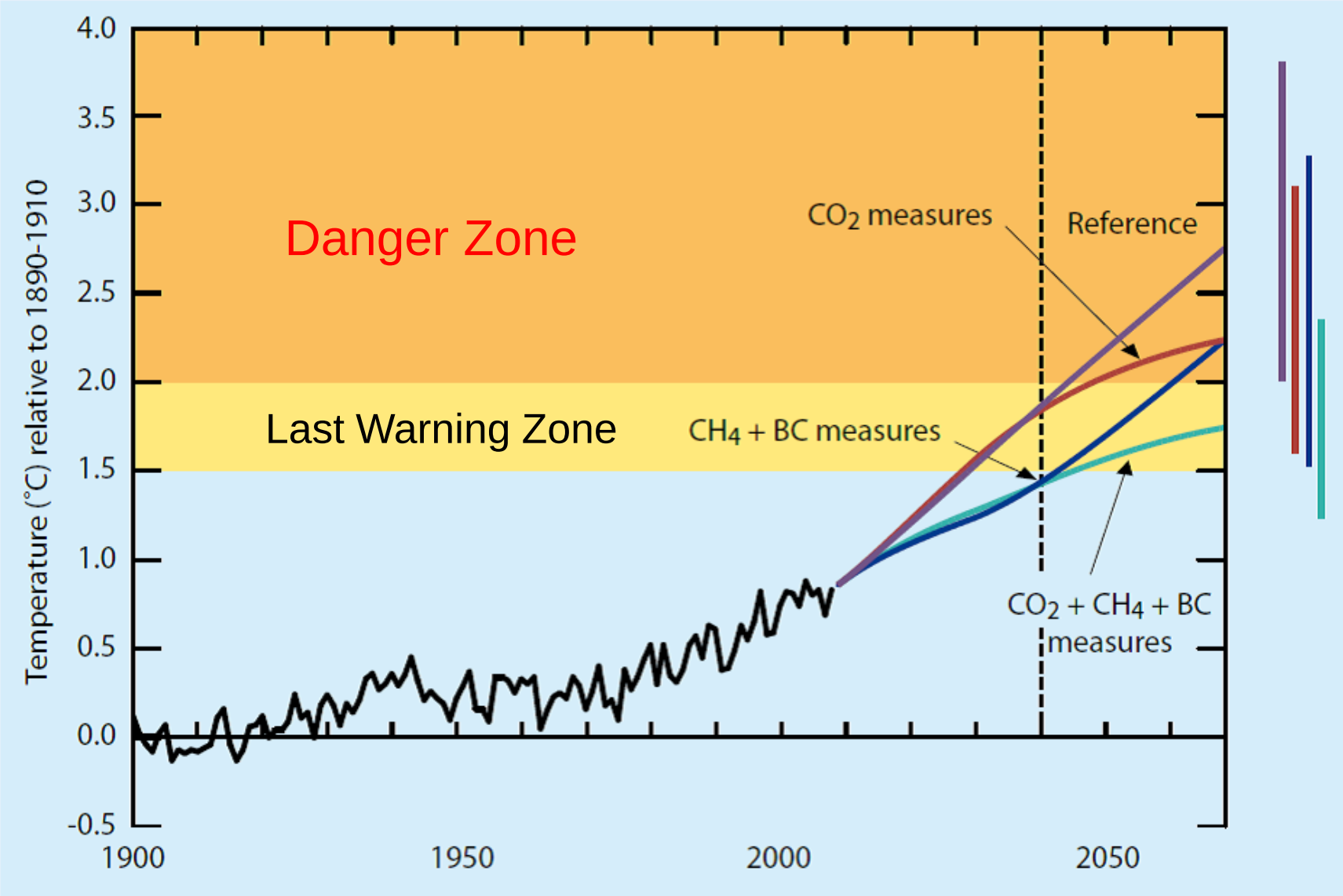
  Each 1% lifetime production leakage from a well produces about the same climate impact as burning the methane twice.

*Shindell DT, Faluvegi G, Koch DM, Schmidt GA, Unger N, and Bauer SE (2009). Improved attribution of climate forcing to emissions. *Science* 326: 716-718.




Howarth, Ingraffea, NATURE, 477, 2011

# Why Is Controlling Methane ($CH_4$) Emission So Important?




Shindell, *et al. Science* ***335, 183 (2012)***

# Burn-Offs at MarkWest Gas Processing Plant, Houston, PA: THIS Is Black Carbon

9/18/11
2:03pm

Photos courtesy of Robert Donnan

# Burn-Offs at MarkWest Gas Processing Plant, Houston, PA: THIS Is Black Carbon

# NO to HVHF, YES to a Much Better Plan

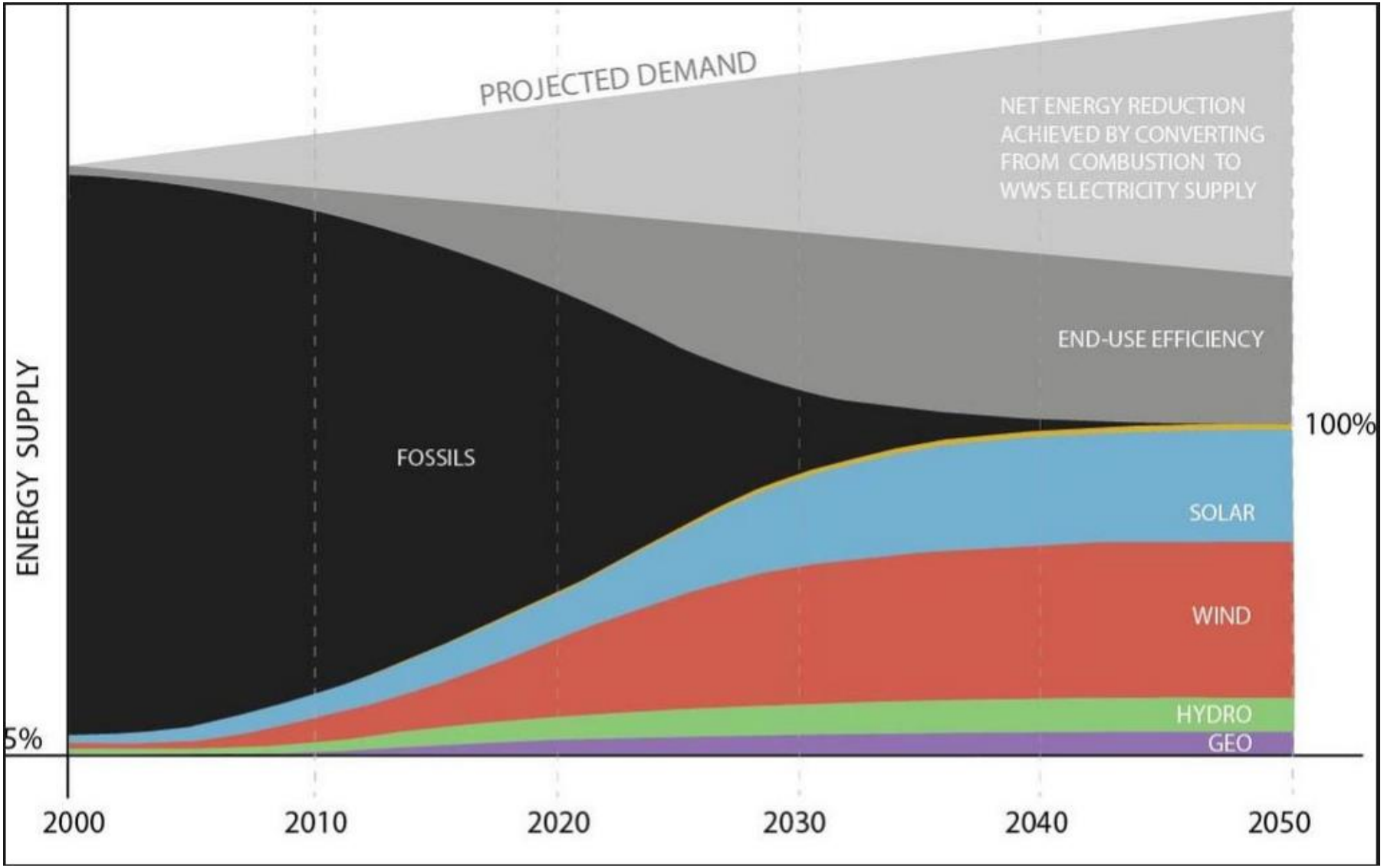
Convert New York State's (NYS's) all-purpose -- electricity, transportation, heating/cooling, industry -- energy infrastructure to one derived entirely from wind, water, and sunlight (WWS), by 2030.

**We the people own the sun. We own the wind. We own the water. Those fuel costs are $0.00.**

Or, NYS can have 50,000 to 100,000 Marcellus and Utica Wells;

- 8,000 to 16,000 pads;
- 500 to 1,000 compressor stations;
- Thousands of miles of new pipelines;
- Thousands of incidents of well water contamination;
- Increase New York's contribution to global warming;
- Continue illness and morbidity from pollution;
- Sequester forever twice the tonnage of the US Navy in non-recyclable steel casing.

# Our Energy Plan for New York State




Jacobson et al., *Energy Policy*, Feb. 2013

# We Own the Wind, the Sun, the Water: Their Fuel Cost is Zero.

Wind, water and solar energy will provide a stable, renewable source of electric power not subject to the same fuel supply limitations as fossil fuels and nuclear power. Due to the eventual depletion of coal, oil, natural gas, and uranium resources, their prices will continue to rise.

# We Own the Wind, the Sun, the Water: They Make Us Energy Secure and Independent

# “There is no time to waste….”

“Natural gas is a delaying tactic…There is no time to waste… We have to decide whether we are in the business of delaying bad outcomes or whether we are in the business of preventing bad outcomes.”

Ken Caldiera, Senior Scientist
Department of Global Ecology,
Carnegie Institution, Stanford, CA
April 15, 2012

# Where Can You Find Reliable Information?


http://www.psehealthyenergy.org/

# Where Can You Find Reliable Information?

PROTECTING COMMUNITIES AND THE ENVIRONMENT

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VISIT THE SITE

## OIL & GAS ACCOUNTABILITY PROJECT

EARTHWORKS' Oil & Gas Accountability Project works with tribal, urban and rural communities to protect their homes and the environment from the devastating impacts of oil and gas development. Learn more.

### HOT ISSUES

**New Mexico showdowns over common sense drilling protections: drilling rules under attack in court and legislature**

*Feb 22* -- The battle over New Mexico's landmark Pit Rule -- the nation's most protective measure to safeguard citizens, water and land from hazardous oil and gas drilling wastes -- is building to a showdown in the courthouse and the Roundhouse (NM's Capitol).

In December District Judge Barbara Vigil heard arguments from the New Mexico Oil and Gas Association, which is seeking to overturn the Pit Rule in its entirety. Tomorrow (2/23) she will hear

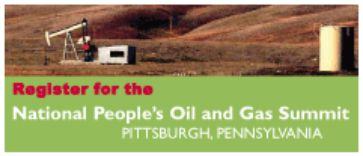
http://www.earthworksaction.org/oil_and_gas.cfm

Rule.

**More info:**

- Read our press release.
- The Albuquerque Journal's recent story gives some political context to the showdown.
- newmexicocommonsense.org provides fact sheets that explain why New Mexico's pit rule is, in fact, common sense. And why industry's arguments against it are bunk.
- Background on what the New Mexico pit rule is.

**On November 19th and 20th, the 2010 National People's Oil & Gas Summit was held in Pittsburgh, Pennsylvania, the heart of the Marcellus Shale natural gas drilling boom.**




The Summit was a huge success with more than 250 citizens from 26 states and Canada joining together to share information, stories, and strategies.

**Click here to view the agenda and download copies of presentations and materials from the 2010 National People's Oil & Gas Summit.** (Video clips from the Summit will be available

**COMMUNITY VOICES**

**Buffalo, WY**

"Reaching an Agreement: Luck of the Draw" provides an account of Pete Dube's efforts to achieve a Surface Use Agreement with a company. Even with that agreement, he struggled to get the company to deal with methane gas that started seeping into his stock well soon after the company drilled a CBM well on a neighbor's property.

**PUBLICATIONS**

**Joint letter to House**

estate amendment. Vote "yes" on passage HR 3534

**Oil and Gas Pollution Fact Sheet**

Contaminants associated with the various stages of oil and gas development

**Our Drinking Water at Risk**

What EPA and the Oil and Gas Industry Don't Want Us to Know About Hydraulic Fracturing. (Full Report)

**Oil and Gas at Your Door? (2005 Edition)**

A landowner's guide to oil and gas development.