Anthony Ingraffea- "Lethal Gas/Oil Wells in Pennsylvania"
(A 21-minute seminar in NY State 13Dec2013. www.youtube.com/watch?v=Dxis-yYGM_M)

A leaking well can emit methane and/or contaminated groundwater. How common are such failures?

Various industry sources estimate that 30% or more of all gas/oil wells are leaking because of faulty cement and/or casing.

Picture -- frack liquid and gas bubbles surging up on the outside of the vertical well production pipe. Frack fluid and the gas CH4 should be inside the pipe, but they are obviously coming up uncontained, releasing the CH4 into the atmosphere and possibly contaminating groundwater on the way to the surface.

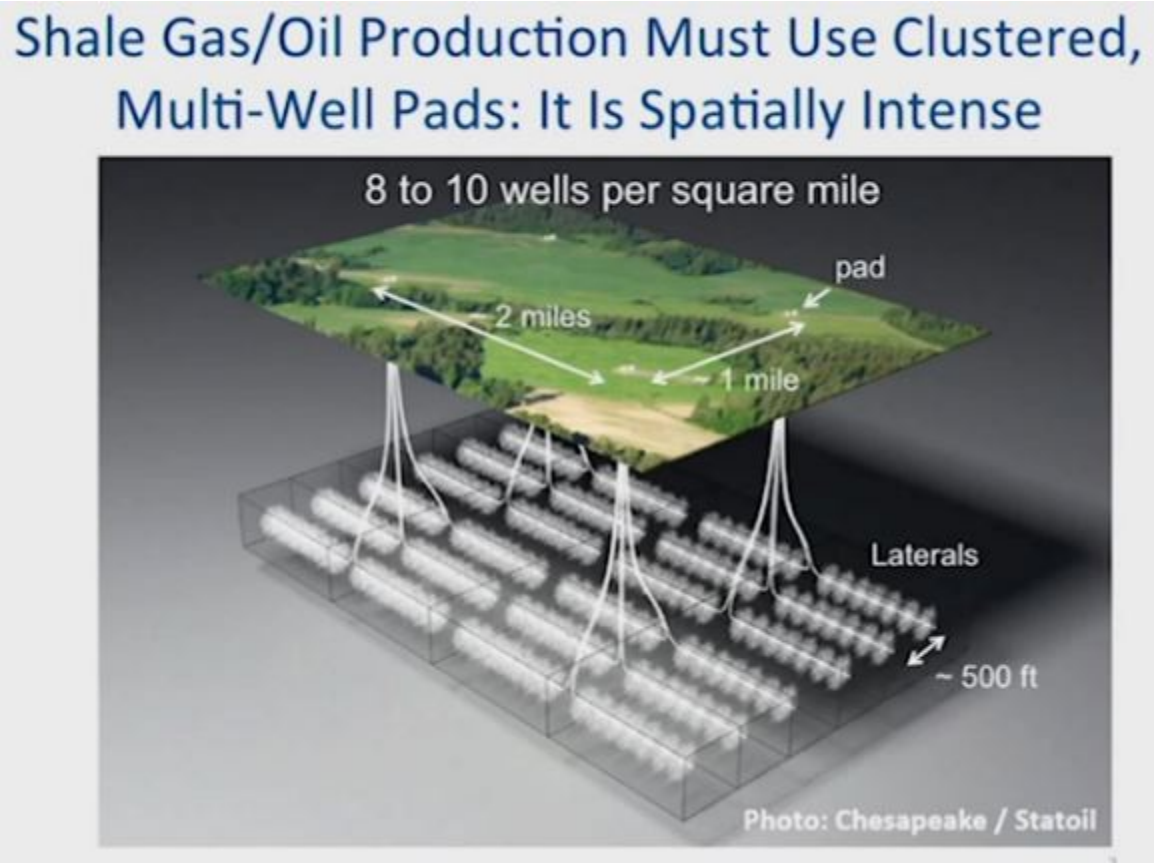
[Wikipedia: "Methane in the Earth's atmosphere is an important **greenhouse gas** with a **global warming potential** of 34 over a 100-year period. This means that a methane emission will have 34 times the impact on temperature of a carbon dioxide emission of the same mass over 100 years. Methane has a large effect for a brief period (having a half-life of 7 years in the atmosphere[4]), whereas carbon dioxide has a small effect for a longer period (over 100 years). Because of this difference in effect and time period, the global warming potential of methane over a 20-year time period is 86. The Earth's methane concentration has increased by about

150% since 1750, and it accounts for 20% of the total radiative forcing from all of the long-lived and globally mixed greenhouse gases."]

Methane and the toxic chemicals in fracking fluid can contaminate underground aquifers and private wells. The gas is most potent in capturing heat in the first years, but it deteriorates naturally, losing its heating absorbing strength, which drops to a potency average of 34 according to IPCC AR 5(25 is an older value from IPCC AR 4) x CO_2 by 100 years.

How often can wells leak? Need to know this to predict how commonly wells can leak. NY State -If fracking is accepted, predict some 30,000 to 90,000 wells. So we need to know how frequently the wells are going to be drilled, and how frequently the wells will fail.

Shale gas development very different from conventional oil/gas. Conventional uses just the vertical wells, but shale gas uses the vertical plus horizontally directed bores. Basic difference is you need an awful lot more vertical wells, and at the bottom of these they use horizontally directed bores to effectively tap the CH_4 trapped in the shale layer.



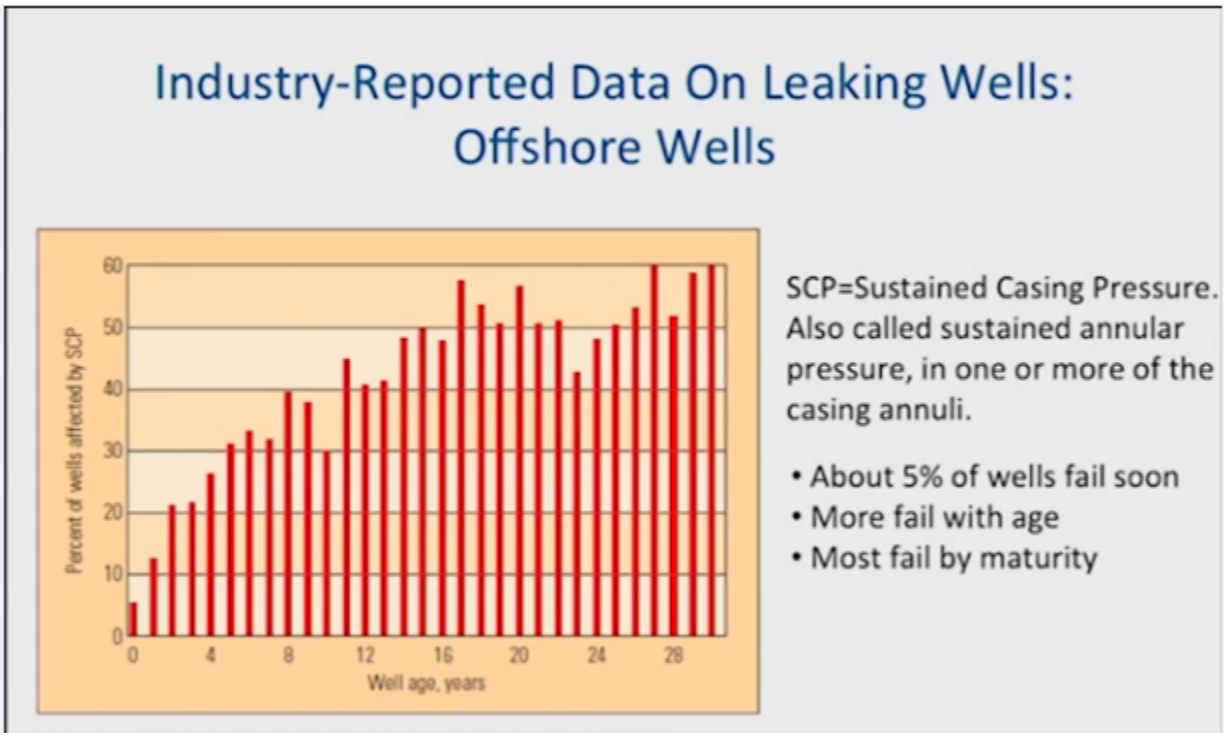
Typically there are 8 to 10 wells per pad and 1 pad/mi^2. They use multi-well pads--it is spatially intense. At each pad there can be different arrangements-- 6 to 8 to 10 wells. Underground, the vertical wells go down to the shale layer, some 1000s of feet below surface. When in the shale the bore drill is turned horizontally and follows the shale long distances, up to 2 miles or more. Several horizontal lines can diverge from one pad. The objective is to penetrate the shale with a dense horizontal system and extract as much gas as possible (e.g., 3 parallel horizontal bore holes might be ca. 500 ft apart going in one direction, and 3 bore holes going out in opposite direction).

Shale gas cannot be developed economically without drilling many wells per pad. Spatially intense placement of pads. So landowner must ask how many well pads are near his/her home, do the horizontal bore holes come close to the home, and what is probability any one well will leak? Probability of well cement and/or casing failure goes up in direct proportion to the number of wells.

The first thing is to do a literature search. The Columbus Dispatch 08Aug2013. "Gas leaks from shale wells are rare." But often this kind of statement is not a scientifically based statement, but probably an opinion given by the company, and does not represent a serious peer-reviewed study.

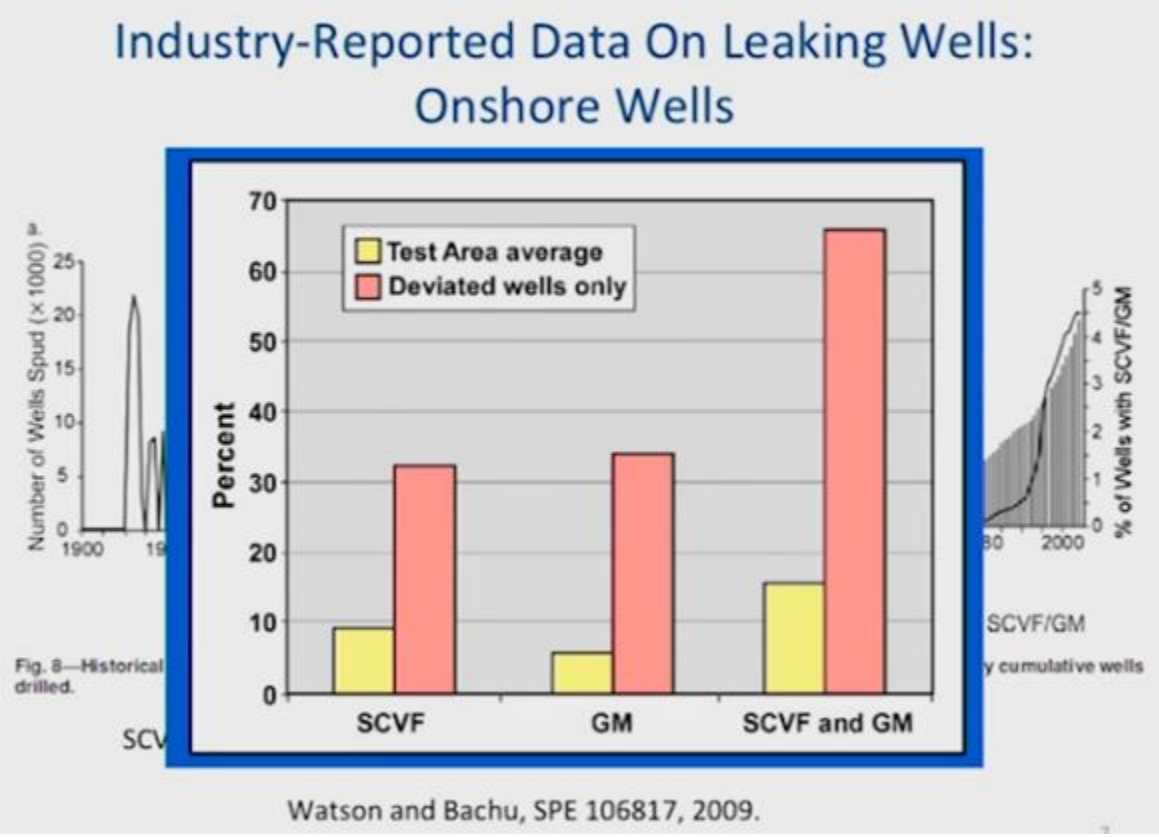
So next go to industry literature. There is lots, over 260,000 papers by Society of Petroleum Engineers, over last 100 years. But none of these are truly peer-reviewed. Some of these are self advertisements.

Bruffalo et al. Oilfield Review. Schlumberger. Industry reported data on leaking wells--offshore wells. One-half were leaking by 15 to 20 years:



Another paper Watson & Bachu, SPE 106817, 2009. Canada 340,000 oil&gas wells in western Canada.

Since 1870s ca. 5 million wells have been drilled!
% wells leaking -- by Sustainable Casing Vent Flow (SCVF), OR by Ground Migration (GM). Ground migration is where there is no evidence of leaking at well head, BUT some distance away, maybe a mile, gas is seen coming up in a field or in a creek or pond.



If wells conventional, straight down only (Test Area), leakage 15-16%, but if they are modern deviated wells (don't only go straight down, also deviated horizontally from vertical):

Leakage rates on Deviated

SCVF-	30%
GM-	33%
SCVF + GM	65%

**Industry continually sponsors conferences on leaking wells, while proclaiming to public that VERY FEW WELLS LEAK!

Soc. Petrol. Engineers, Webinar on Wellbore Integrity, Paul Hopman, 27Mar2013 (Ingraffea attended this.)

- ! Industry will drill more wells in next decade than have been drilled in last 100 years
- ! Global well population is +/- 1.8 million (in this data set), of which +/- 35% have 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

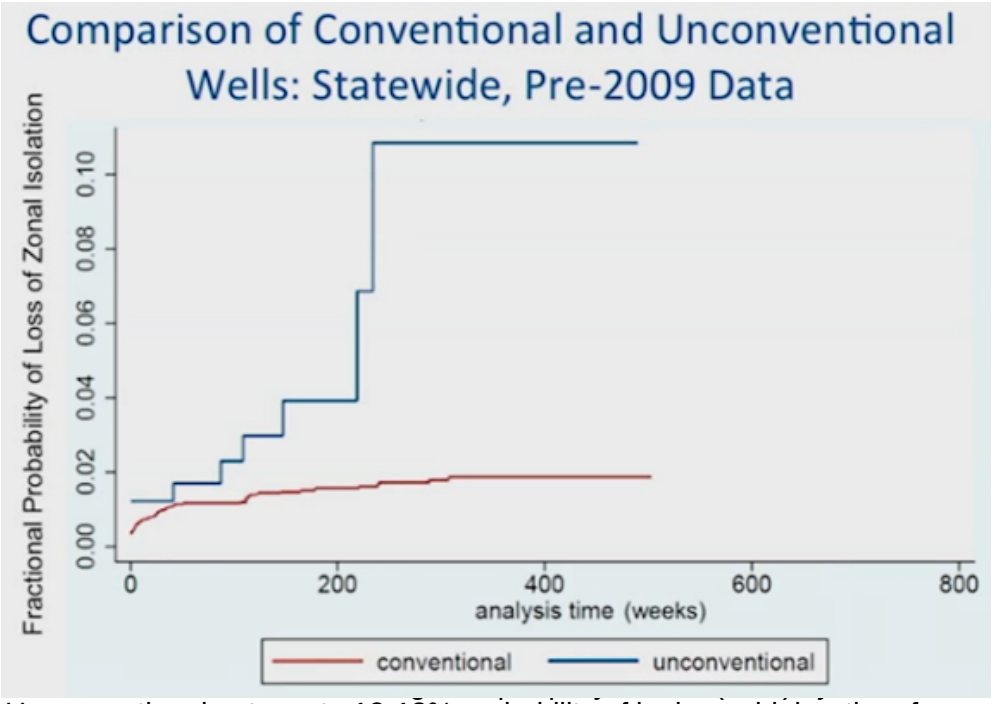
More industry statistics on leaky wells
-George E. King Consulting Inc. Writes lots of papers that report that wells don't leak. But continues to consult to document rates of leakage. http://gekengineering.com/id6.html

young wells	5% leaks
older wells	30 to 35% leaks

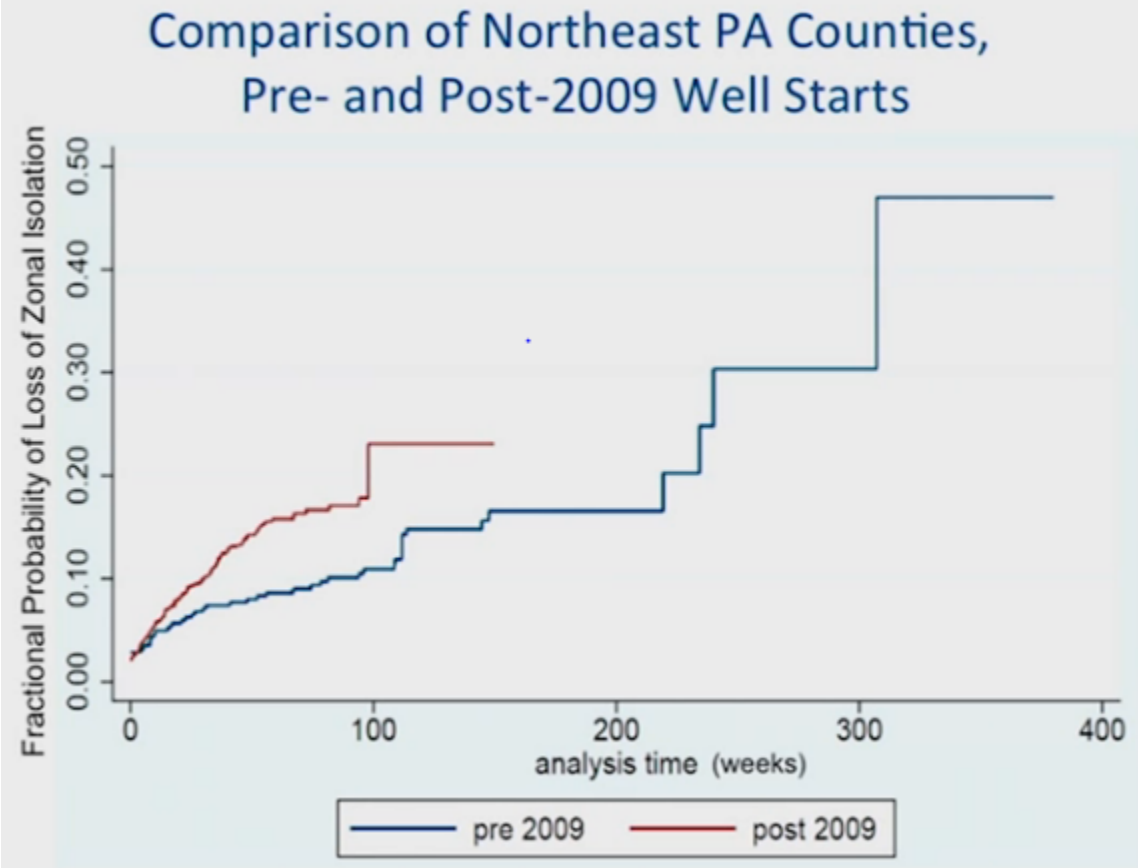
So then Ingraffea asked what about modern wells, which aren't supposed to leak!

1) Ingraffea went to records in Penn Environ Protection Department. Created a data base of 75,000 inspection and violation records for over 41,000 gas and oil wells drilled in Penn between 01Jan2000 and 31Dec2012.
2) Mined the data to identify all wells with wellbore integrity problems.
3) Statistically analyzed results: Cox Proportional Hazard Model. With the large data set he could parse the data and make comparisons in many different ways.
4) First preliminary results presented here. Paper on this research has been accepted for publication in 2014.

He used Pennsylvania as predictor to what we might see in NYState.
Studied conventional (vertical only) and non-conventional (fracked, horizontal bore) As wells age, probability of leaking goes up.



Unconventional gets up to 12-13% probability of leakage, higher than for conventional. Not inspecting older wells any longer. Pre-2009 wells 50% leaking after 400 weeks.



Observations and Implications

- Cement and/or casing failure is ubiquitous, everywhere, also in Canada. A chronic and well-known mode of loss of wellbore integrity (known since 1913)
- Thorough analysis of well integrity data in 'modern' shale wells indicates significant failure rate
- Support for hypothesis that methane and frack liquid migration incidents are resulting from 'leaky' wells

With 25,000 to 30,000 shale gas/oil wells per year in the U.S.A., many contamination incidents are likely to occur, and methane emissions will increase.

Hundreds of Pennsylvania families have lost access to their water wells. Confirmed by Penn Dept Environmental Protection. So far only 6800 wells in NY. But if one expects 100,000 wells to be drilled, and you believe this data, 10s of 1000s will lose access to their water wells.

25,000 to 30,000 wells will be drilled per year in the U.S.A. Vast majority of these are in shale. Many more water well contamination incidents will occur based on these statistics, AND there will be a lot more methane emitted from leaking wells.

Ingraffea: The only way to get operators to reduce or stop production. DECREASE THE DEMAND! Let the people running the show know that you don't need the fossil fuels. You can get by with something else.

This material has been accepted for publication in 2014. See below