What Would Willie Sutton Say About Hydraulic Fracturing of the Marcellus Shale?

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William N. Rom Symposium
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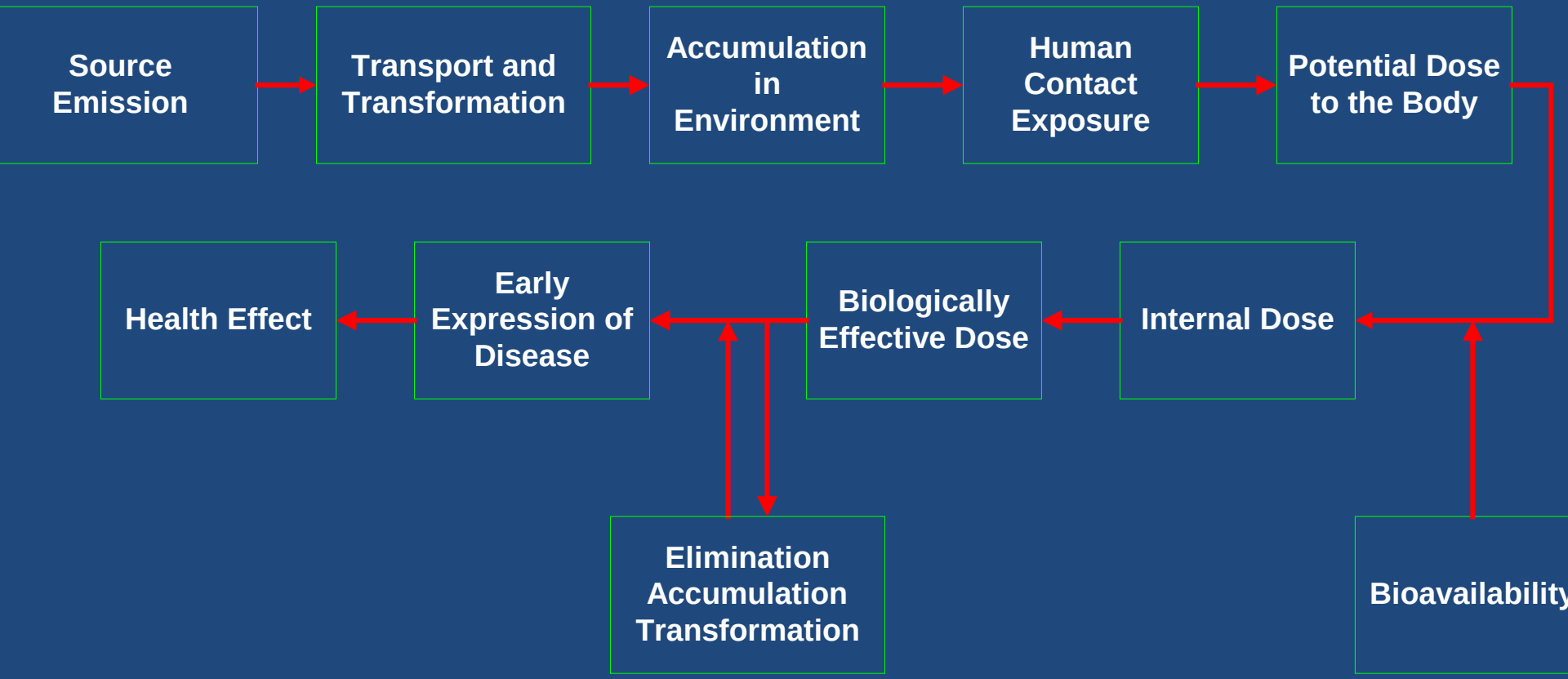
Willie Sutton

SUTTON'S LAW AS A JUSTIFICATION FOR STUDYING ***HUMANS*** IN RELATION TO THE POTENTIAL HEALTH EFFECTS OF UGD

Continuum for the Emission of and Exposure to a Contaminant and the Expression of a Health Effect

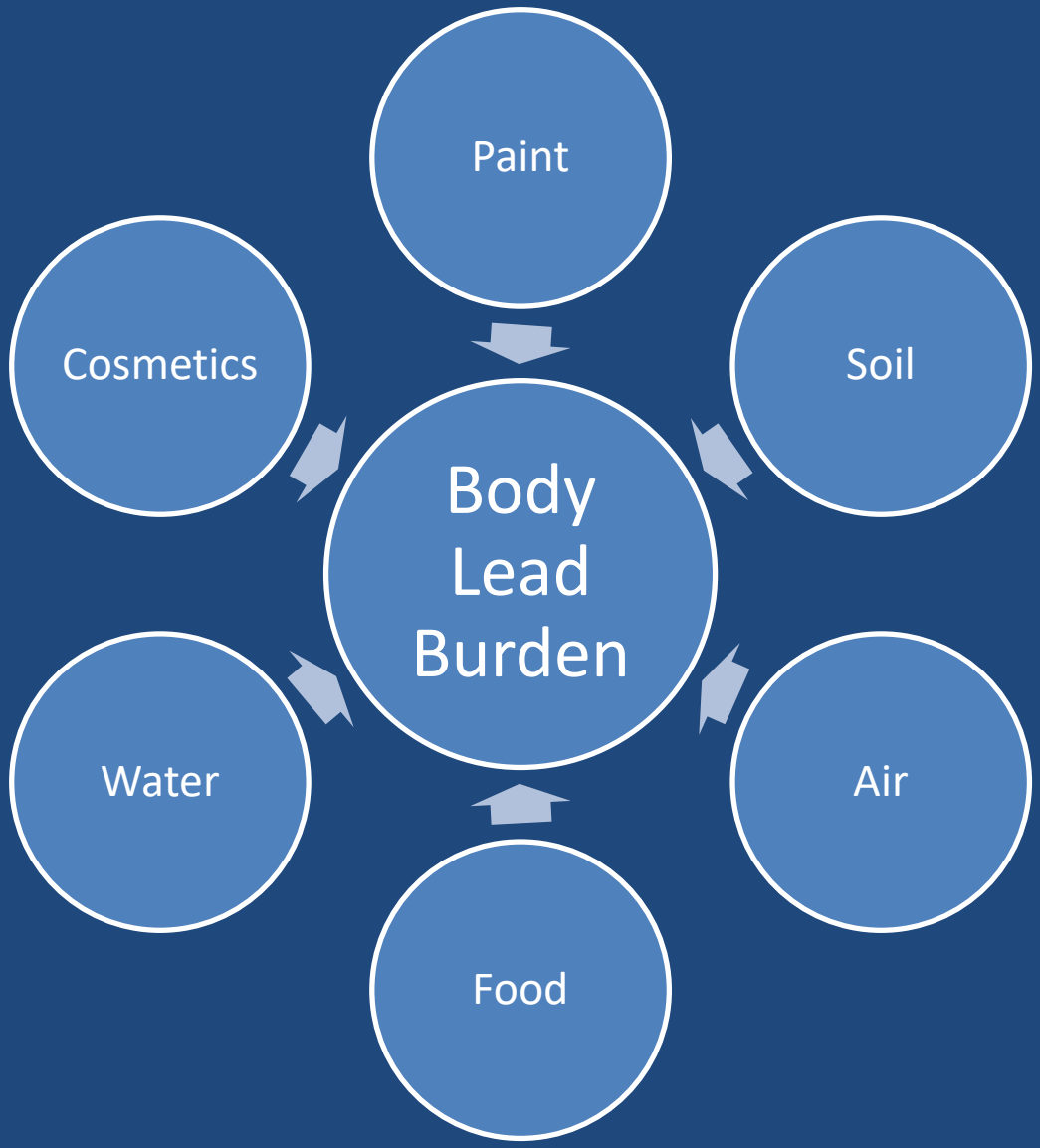


P.J. Lioy, Env. Sci. & Tech. 1990

Potential Health Benefits of Natural Gas Development

- Replacement of coal in power generation leading to lesser emissions of particulates, sulfur oxides, nitrogen oxides and mercury

- Probable decrease in greenhouse gas impact of fossil fuels


Paint
Soil
Air
Food
Water
Cosmetics
Body Lead Burden

Sutton's Law: Requires Direct Measurement of Exposures or Effects in the Receptors of Concern

Sutton's Law may be violated if:

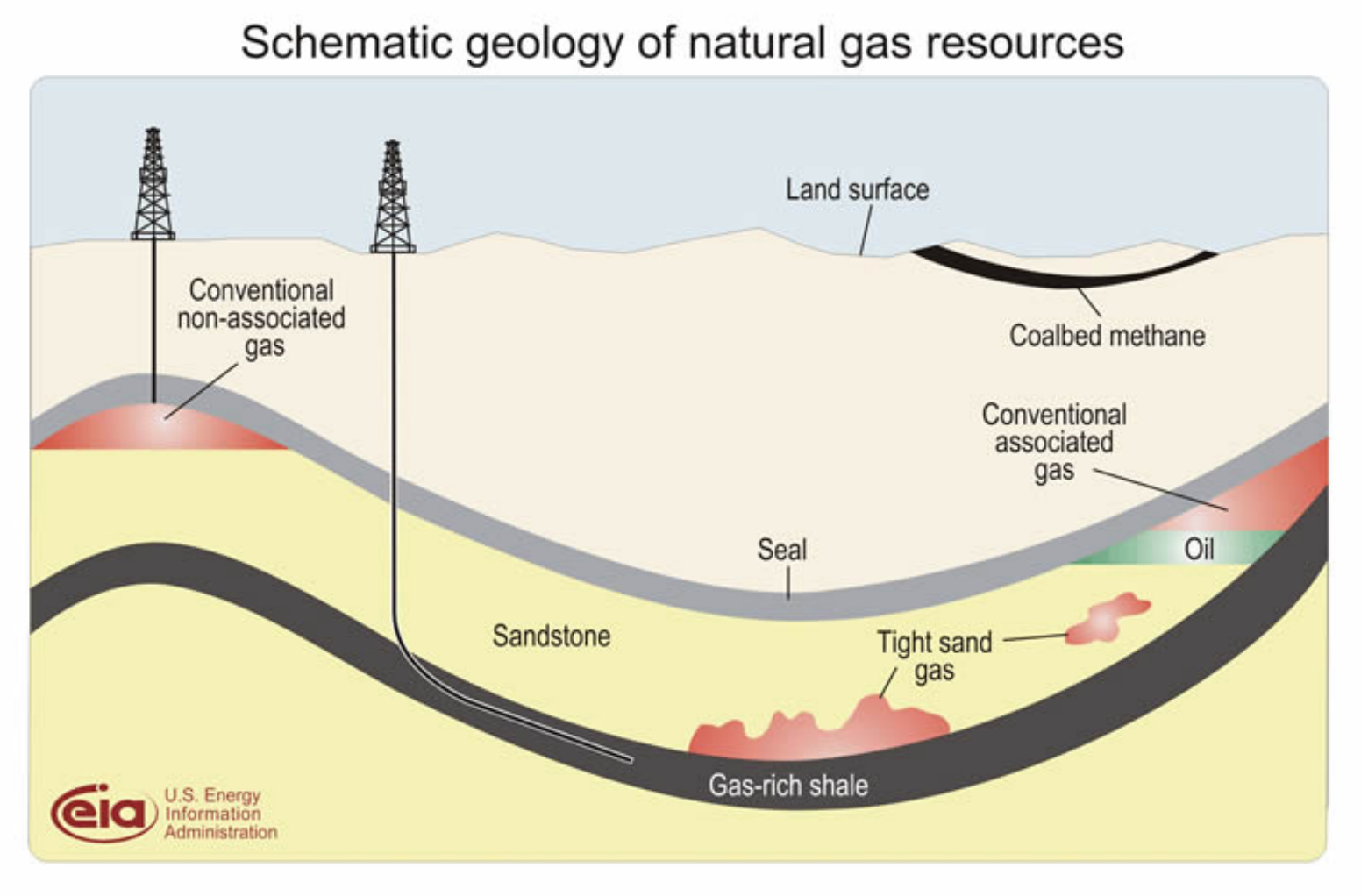
1. The technological processes possibly leading to release of of the chemical and physical agents of concern are reasonably well understood.
2. The chemical and physical agents of potential concern are known and can be measured
3. The source and geographical location of the releases can be reasonably identified
4. There is information about the likely temporal patterns of the releases in relation to the temporal patterns of receptor activity and susceptibility

US Steel: Clairton, PA

Many Agents of Potential Concern

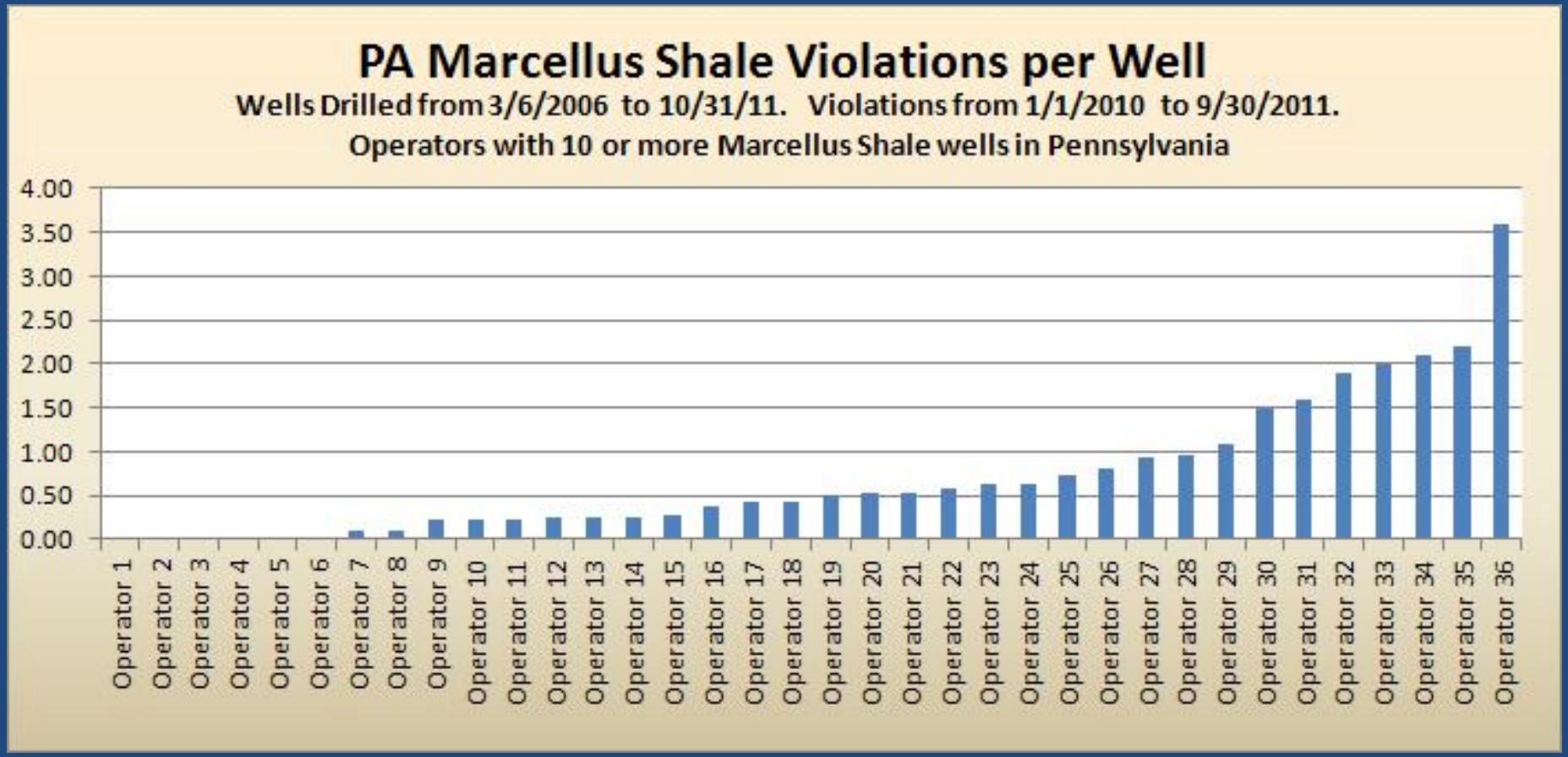
- Three sources of toxicologically relevant agents
  - Hydrofracturing agents
  - Hydrocarbons and gases present in shale; methane, ethane, propane, BTEX, hydrogen sulfide
  - Natural constituents: brine components; barium, bromide, calcium, chloride, iron, magnesium, strontium; arsenic; radionuclides
  - ***Mixtures of any or all of above***
- Chemical reactions favored by higher temperatures and affected by other local conditions
  - Temperature in shale that favors natural gas production is ~480F
  - High pressure and salinity

Conventional and Non-conventional Natural Gas Extraction Methodologies



Why Exposure Can Vary Greatly From Site to Site

- Different safety culture
- Different geology
- Different site-specific issues
- Different drilling technology
- Different hydraulic fracturing chemicals
- Different shale gas collection and distribution techniques
- Different flowback disposal techniques



Source: FracTracker. (2011). *FracTracker.* Retrieved Jan 11, 2012, from http://www.fractracker.org/

Measurements of methane emissions at natural gas production sites in the United States

David T. Allen, Vincent M. Torres, James Thomas, David W. Sullivan, Matthew Harrison, Al Hendler, Scott C. Herndon, Charles E. Kolb, Matthew P. Fraser, A. Daniel Hill, Brian K. Lamb, Jennifer Miskimins, Robert F. Sawyer, and John H. Seinfeld.

PNAS 110:17768–17773, 2013

Sponsors

- Environmental Defense Fund
- Anadarko Petroleum Corporation
- BG Group plc
- Chevron
- Encana Oil & Gas (USA) Inc.
- Pioneer Natural Resources
- SWEPI LP (Shell)
- Southwestern Energy
- Talisman Energy USA
- XTO Energy, an ExxonMobil subsidiary

- Allen, D. T., Torres, V. M., Thomas, J., Sullivan, D. W., Harrison, M., Hendler, A., . . . Seinfeld, J. H. (2013). Measurements of methane emissions at natural gas production sites in the United States. Proceedings of the National Academy of Sciences. doi: 10.1073/pnas.1304880110

Measurements of methane emissions at natural gas production sites in the United States

- Measurements were made of methane emissions during 27 completion flowback events.
- The duration of the completions ranged from 5 to 339 h (2 wk). ***Measured methane emissions over an entire completion flowback event ranged from less than 0.01 Mg to more than 17 Mg*** with an average of 1.7 Mg and a 95% confidence interval of 0.67-3.3 Mg.
- Potential emissions for the wells in this work ***ranged from 0.2 Mg to more than 1 Gg methane***, with an average of 124 Mg.

Allen, D. T., Torres, V. M., Thomas, J., Sullivan, D. W., Harrison, M., Hendler, A., . . . Seinfeld, J. H. (2013). Measurements of methane emissions at natural gas production sites in the United States. Proceedings of the National Academy of Sciences. doi: 10.1073/pnas.1304880110

Measurements of methane emissions at natural gas production sites in the United States

- Average methane emission rates for a single unloading ranged ***from roughly 100 g/min to in excess of 30,000 g/min.*** These rates are much larger than emission rates for production sites (typically tens of grams of methane per minute per well) or from completions (typically a few hundred grams per event per minute). ***At these emission rates, a single unloading event could, during the short period that it is occurring, result in emissions that are the equivalent of up to several thousand wells in routine production.***

Allen, D. T., Torres, V. M., Thomas, J., Sullivan, D. W., Harrison, M., Hendler, A., . . . Seinfeld, J. H. (2013). Measurements of methane emissions at natural gas production sites in the United States. Proceedings of the National Academy of Sciences. doi: 10.1073/pnas.1304880110

Principles that Underpin an Effective Monitoring Program

(Based on the report of the Integrated Oil Sands Monitoring Plan Expert Panel– Environment Canada, 2011)

- **Adaptive and robust**
- **Inclusive and collaborative**
- **Holistic and comprehensive**
- **Scientifically rigorous**
- **Transparent and accessible**