Examining the association between **unconventional natural gas development** and **health**

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(with several slides from Dr. Brian S. Schwartz, MD, MS,
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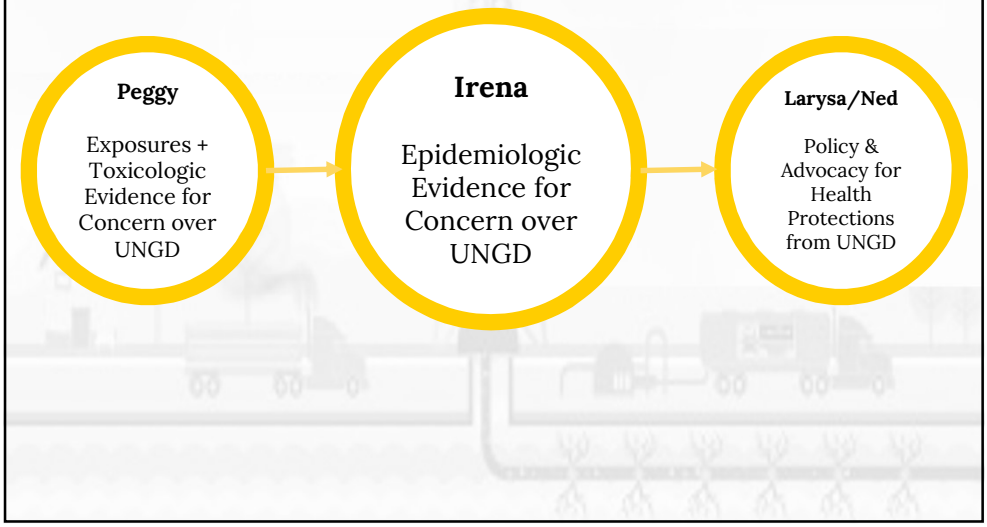
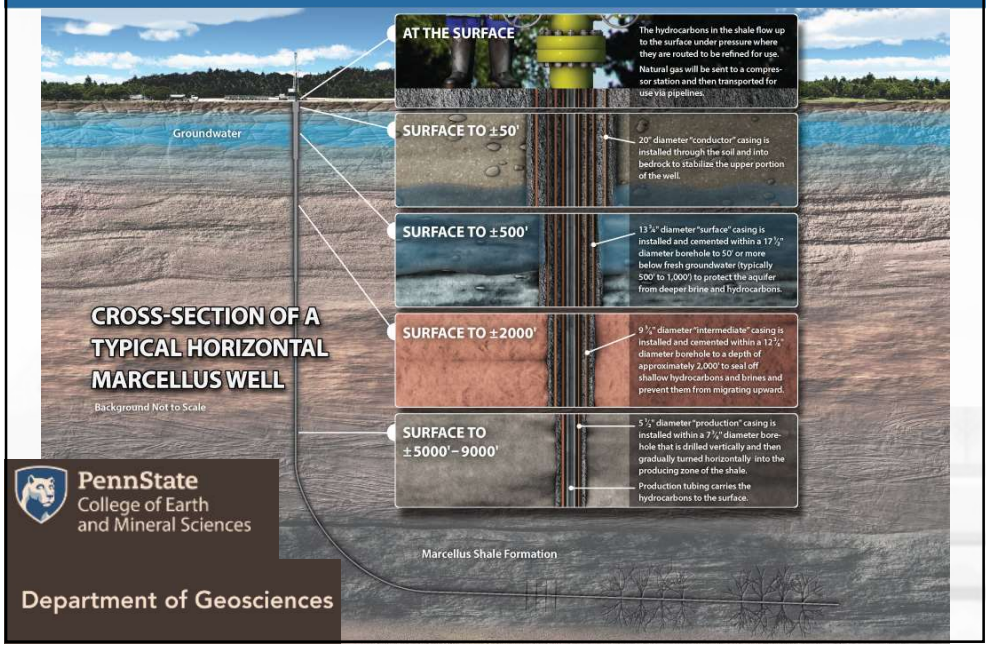
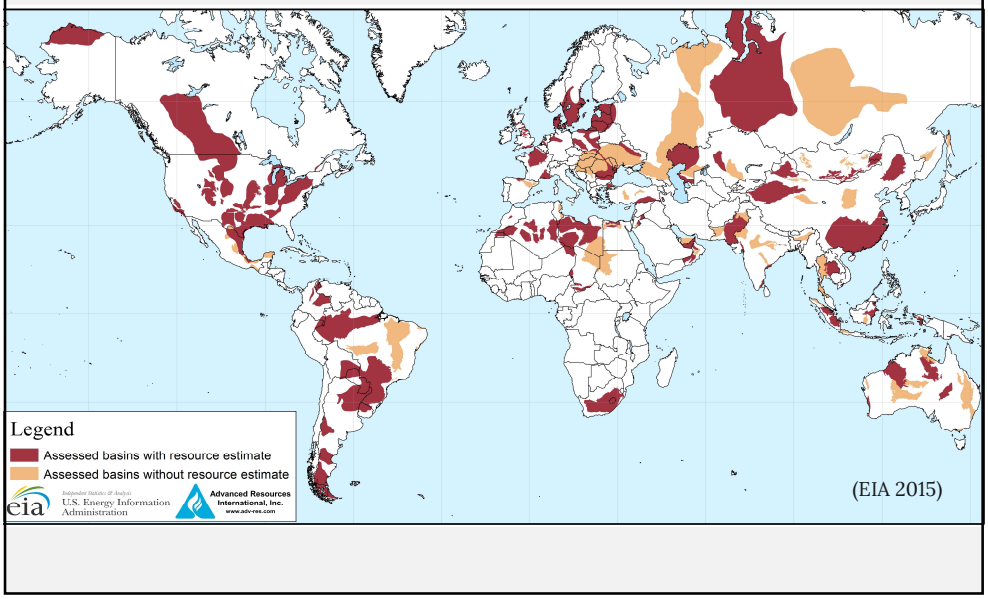
Flow of tonight's presentations



UNGD Geology 101



PA accounts for ~25% of current U.S. production



Environmental Epidemiology 101

Epidemiology *is the study of the* ***distribution and determinants of health-related states or events*** *in specified populations, and the application of this study to the control of health problems.*

-John Last, Dictionary of Epidemiology, 2001

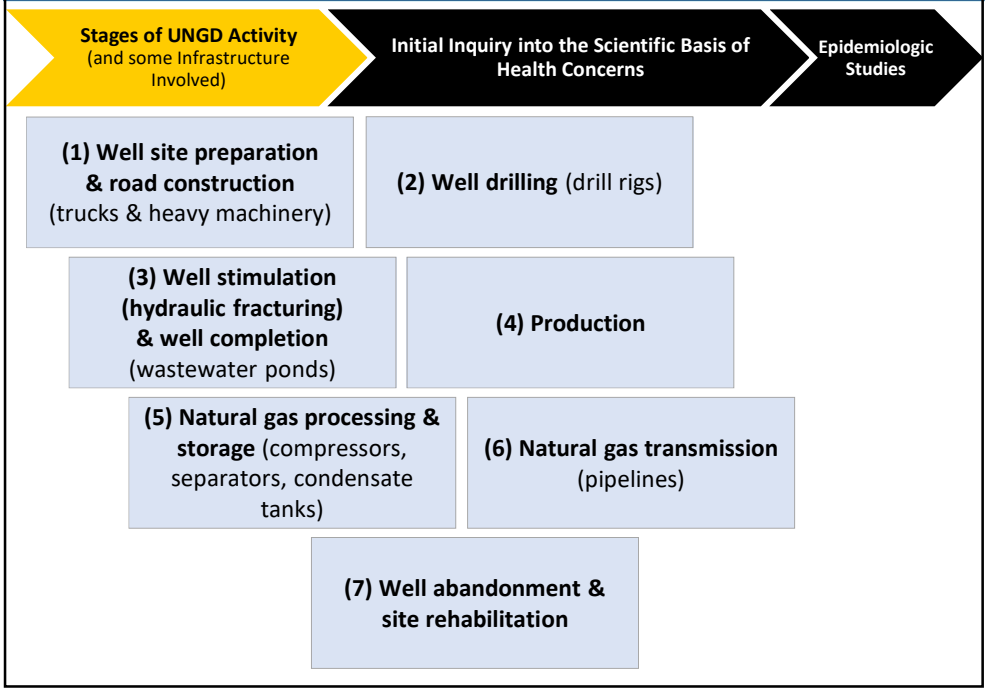
1) Use prior knowledge to **develop hypotheses** about whether & how factors of interest could impact health.

2) Measure **environmental exposure.**

3) Measure **health outcome.**

4) Use **biostatistics to identify associations** and eliminate chance as an explanation for findings, adjusting to control for influence of confounders.

1) Develop hypotheses: Could UNGD Affect Children's Health?



1) Develop hypotheses: Could UNGD Affect Children's Health?

Stages of UNGD Activity (and some Infrastructure Involved) → **Initial Inquiry into the Scientific Basis of Health Concerns** → **Epidemiologic Studies**

Risk assessment studies
Exposure assessment studies
Toxicological studies

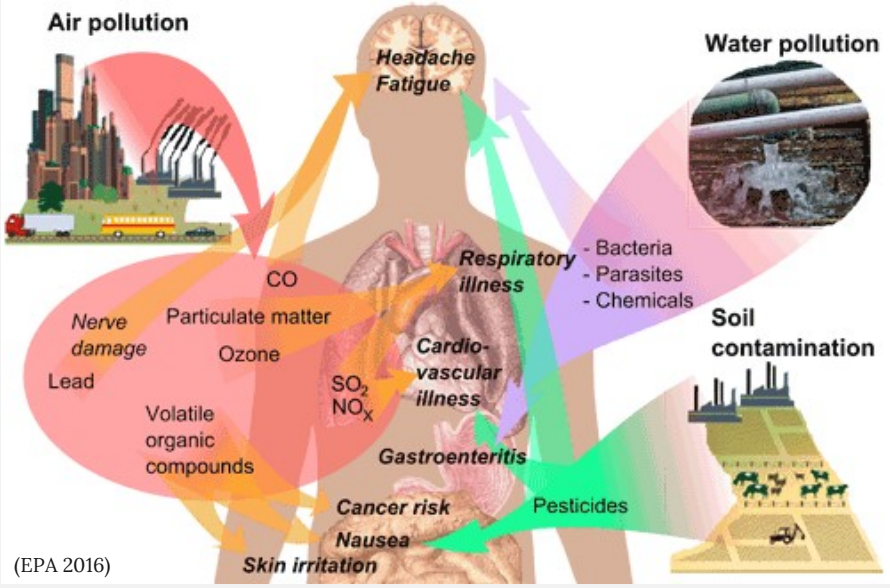
Potential Human Exposures

Individual exposures
- Water pollution
- Air pollution
- Soil contamination
- Physical hazards
- Psychosocial hazards

Community impacts
- Built environment
- Social environment
- Economic environment

Broader environmental threats
- Cumulative impacts from >10k wells over decades

What can environmental pollution do to human health?



(EPA 2016)

Community Context Matters for Health

Just a few examples:

Review article

Contextual effects and cancer outcomes in the United States: a systematic review of characteristics in multilevel analyses — 2017

Annals of Epidemiology

Review article

Area-level socioeconomic disadvantage and suicidal behaviour in Europe: A systematic review — 2017

Social Science & Medicine

Contextual Determinants of Childhood Injury: A Systematic Review of Studies With Multilevel Analytic Methods — 2015

American Journal of Public Health

Community Stress, Psychosocial Hazards, and EPA Decision-Making in Communities Impacted by Chronic Technological Disasters — 2011

American Journal of Public Health

Why children are of extra concern

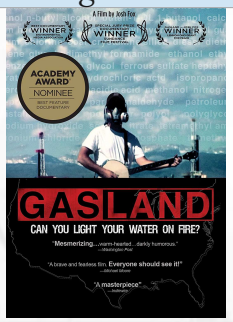
Not small adults -> fetuses, infants, children, and adolescents have unique characteristics that heighten susceptibility to environmental exposures:

- Biologic sensitivity (bodies still developing)
- Differences in exposure (eat & drink more per unit body weight, hand-to-mouth activity, more time outdoors)
- Longer future lifespan leads to greater cumulative exposure and more opportunity to develop disease

2) Measure UNGD Exposure

Pathways:

Water Contamination -> Ingestion



Air Pollution -> Inhalation

Noise + Sleep Disturbance + Earthquakes + Community Impacts -> Stress

Challenges:

Funding

UNGD activity past peak -> measuring historical exposures

2) Measure Exposure: Methods Used by Schwartz & Others

$$\text{UNGD Well Activity Metric} = \sum_{i}^{n} \frac{m_i}{d_{ij}^2}$$

- FOUR metrics
- For every well *i* and patient residence *j*
- m_i = 1 for PAD, 1 for SPUD, total depth for STIM, daily gas volume for PROD
- d = distance well to residence
- Four analyzed separately or combined

PAD → SPUD // Median 205d → STIM // Median 66d → PROD →

- Well pad development
- Wells assigned to pads
- Starts 30d before first well on pad spudded, ends on spud date

- Start of well drilling
- Starts with SPUD date
- Ends up to 30d later as linear function of well total depth

- Stimulation
- AKA "fracking"
- Starts with STIM date
- Ends 7 days later
- **NUMERATOR** = total depth

- Production
- Starts day of first non-zero production value
- Continues every day with non-zero value
- **NUMERATOR** = production volume

2) Measure Exposure: Methods Used by Schwartz & Others

UNGD activity metrics get BIGGER if you are surrounded by

Closer wells
More wells
Larger wells

All wells in state contribute:

- Closer: distance residence to well
- More: number of wells
- Larger: total depth (STIM) or volume of production (PROD)

3) Measure Health Outcome

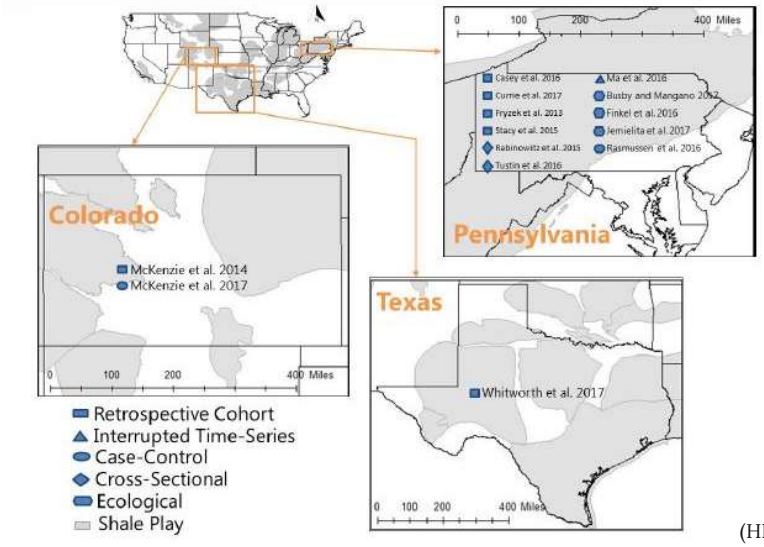
Options:	Challenges:
Governmental databases	Difficult to obtain access to healthcare records
Health records	Bias toward more severe events being recorded in government databases, healthcare records, and surveys
Surveys	

4) Biostatistical analysis

Exposure to UNGD → ? → Incidence, risk, or odds of the health outcome

Evidence of UNGD Affecting Children's Health

Stages of UNGD Activity (and some Infrastructure Involved) → **Initial Inquiry into the Scientific Basis of Health Concerns** → **Epidemiologic Studies**



(HEI 2018)

Health Impact #1: Pregnancy, Birth, and Infant Outcomes

- Higher prevalence of low birth weight *(Hill, 2012; Stacy et al., 2015; Currie et al., 2017)*
- Higher odds of small for gestational age *(Hill, 2012; Stacy et al., 2015)*
- Lower 5-minute Apgar scores *(Hill, 2012)*
- Higher odds of congenital heart defects and neural tube defects *(McKenzie et al., 2014)*
- Lower average birth weight *(Stacy et al., 2015; Currie et al., 2017)*
- Higher odds of preterm birth *(Casey et al., 2016; Whitworth et al., 2017; Whitworth et al., 2018)*
- Higher odds of high-risk pregnancy *(Casey et al., 2016)*
- Higher odds of fetal death *(Whitworth et al., 2017)*
- Lower infant health index *(Currie et al., 2017)*

Health Impact #2: Higher odds of 3 types of asthma exacerbations

Original Investigation JAMA Internal Medicine Published online July 18, 2016

Association Between Unconventional Natural Gas Development in the Marcellus Shale and Asthma Exacerbations

Sara G. Rasmussen, MHS; Elizabeth L. Ogburn, PhD; Meredith McCormack, MD; Joan A. Casey, PhD; Karen Bandeen-Roche, PhD; Dione G. Mercer, BS; Brian S. Schwartz, MD, MS

- **Four UNGD activity metrics**: PAD, SPUD, STIM, and PROD
- **Three asthma outcomes**: mild (OCS), moderate (ED), and severe (HOSP) exacerbations

Table 2. Associations of Unconventional Natural Gas Development Activity Metrics and Asthma Outcomes[a]

- All UNGD activity metrics were associated (OR, 95% CI) with all three outcomes
- Selected associations:

UNGD	PAD with HOSP	SPUD with HOSP	STIM with ED	PROD with OCS
Low	1.26 (1.06-1.50)	1.16 (0.98-1.37)	1.51 (1.05-2.19)	1.28 (1.13-1.46)
Medium	1.37 (1.15-1.64)	1.26 (1.05-1.50)	1.74 (1.17-2.61)	2.15 (1.87-2.47)
High	1.45 (1.21-1.73)	1.64 (1.38-1.97)	1.71 (1.16-2.52)	4.43 (3.75-5.22)

Two sensitivity analyses:

1. County not associated with asthma exacerbations
2. UNGD not associated with **diarrheal illness** among asthma patients

Health Impact #3: Various symptoms

- Higher odds of upper respiratory and dermatologic symptoms *(Rabinowitz et al., 2015)*
- Higher odds of chronic rhinosinusitis, migraine headache, & fatigue symptoms *(Tustin et al., 2017)*

Other Health Studies

- **Health impact assessments** – several (e.g., Witter, *AJPH* 2013; McKenzie, *Sci Tot Env* 2012; Boyle, *PLOS One* 2016)
- **Calls to action** – many (e.g., Finkel, *AJPH* 2013 & 2011; Bamberger, *New Solut* 2012)
- **Review articles, health** – several (e.g., Adgate, *ES&T* 2014; Hays, noise, *Sci Tot Env* 2017; Moore, *ES&T* 2014; Webb, *Rev Env Health* 2016; Hays, *PLOS One* 2016)
  - Hays 2016: "31 original research studies relevant to UNGD and public health hazards, risks, and health outcomes"
- **Qualitative research** – focus groups are concerned about potential health impacts and believe they are experiencing current health effects (e.g., Ferrar, *IJOEH* 2013; Sangaramoorthy, *Soc Sci Med* 2016)
- **Survey research** – mainly convenience samples (e.g., Steinzor, *New Solut* 2013; Powers *J Comm Health* 2015; Saberi *IJERPH* 2014)

Additional strengths & challenges of these epidemiologic studies

Associations robust to increasing covariate control + in several sensitivity analyses

Associations are biologically plausible

Large sample sizes (i.e. >1 million) in many of the studies

Can (should) only be investigating short-latency outcomes at this time (i.e. not cancer yet).

We cannot identify mechanisms.

Threat to science from industry + politics

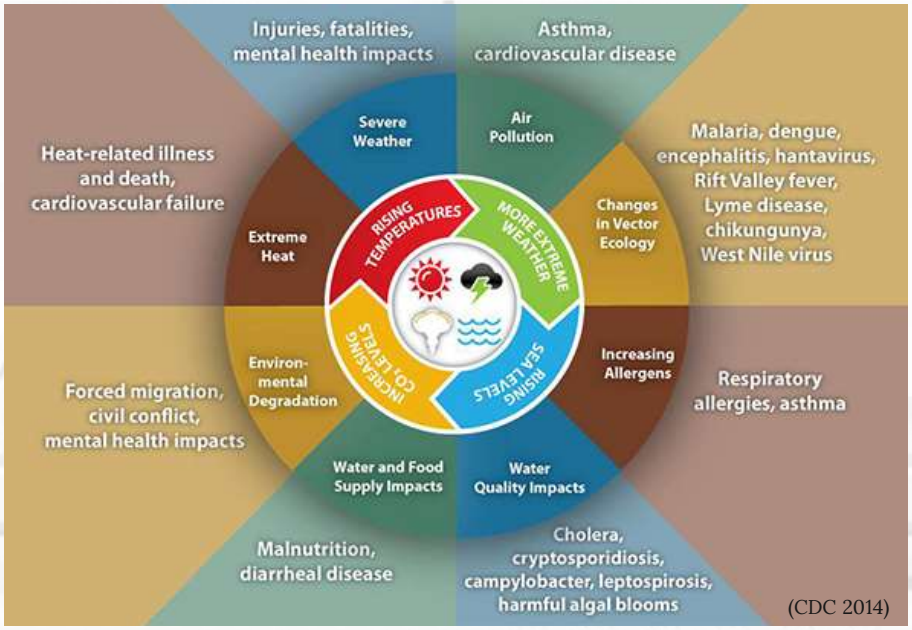
But is it better than coal?

Natural gas is the cleanest burning of the fossil fuels, with lower emissions of carbon dioxide per unit of derived energy and virtually no release of combustion toxicants.

However, low natural gas prices are delaying renewables AND fugitive emissions of methane make UNGD worse for GHG emissions than coal if they exceed ~3% (and estimates range from 1-6%).

(*Allen et al.*, 2013; *Howard*, 2015; *Howarth*, 2015; *Jiang et al.*, 2011)

Contribution to Climate Change -> Health Impacts



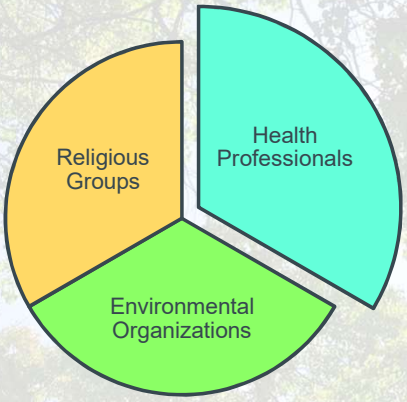
Fracking Ban in Maryland

2015: Maryland passes moratorium on hydraulic fracturing

Fracking Ban in Maryland

2016: Evidence of negative health concerns growing + strong advocacy campaigns

2017: Maryland passes ban on hydraulic fracturing



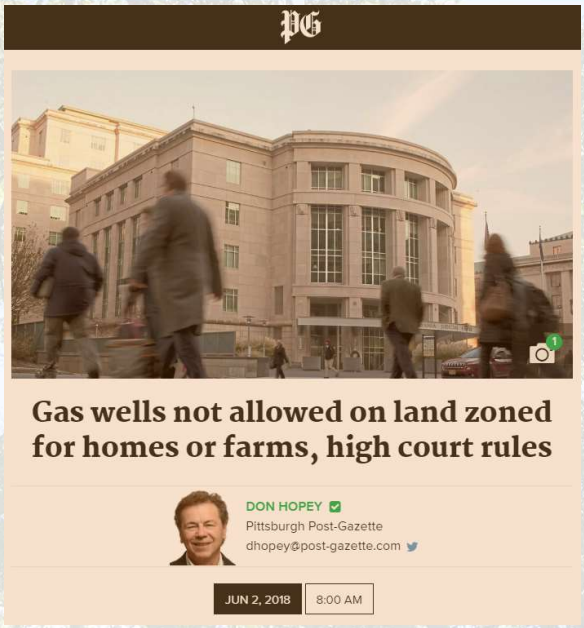
DON'T FRACK MARYLAND

Fracking Ban in Maryland

2018: Still health concerns in MD over pollution from other UNGD infrastructure

- Compressor stations
- Pipelines
- Impoundments

Hope for child health protections in PA?



PG

Gas wells not allowed on land zoned for homes or farms, high court rules

DON HOPEY
Pittsburgh Post-Gazette
dhopey@post-gazette.com

JUN 2, 2018 8:00 AM

Questions?

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https://ehe.jhu.edu/

Thank you to Dr. Brian S. Schwartz for his doctoral advisement and sharing his slides with me to help me make tonight's presentation!