



Environment, Energy, and Economic Development Program

***Estimation of Regional Air-Quality
Damages from Shale Gas Production and
Processing:
A Case Study in Pennsylvania***

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There are Benefits and Risks from Shale Gas And Today We Focus on Air Quality Impacts

- **Background and context**
- **Our analysis of increased air emissions and related damages**
- **Policy implications and relevance to British Columbia**

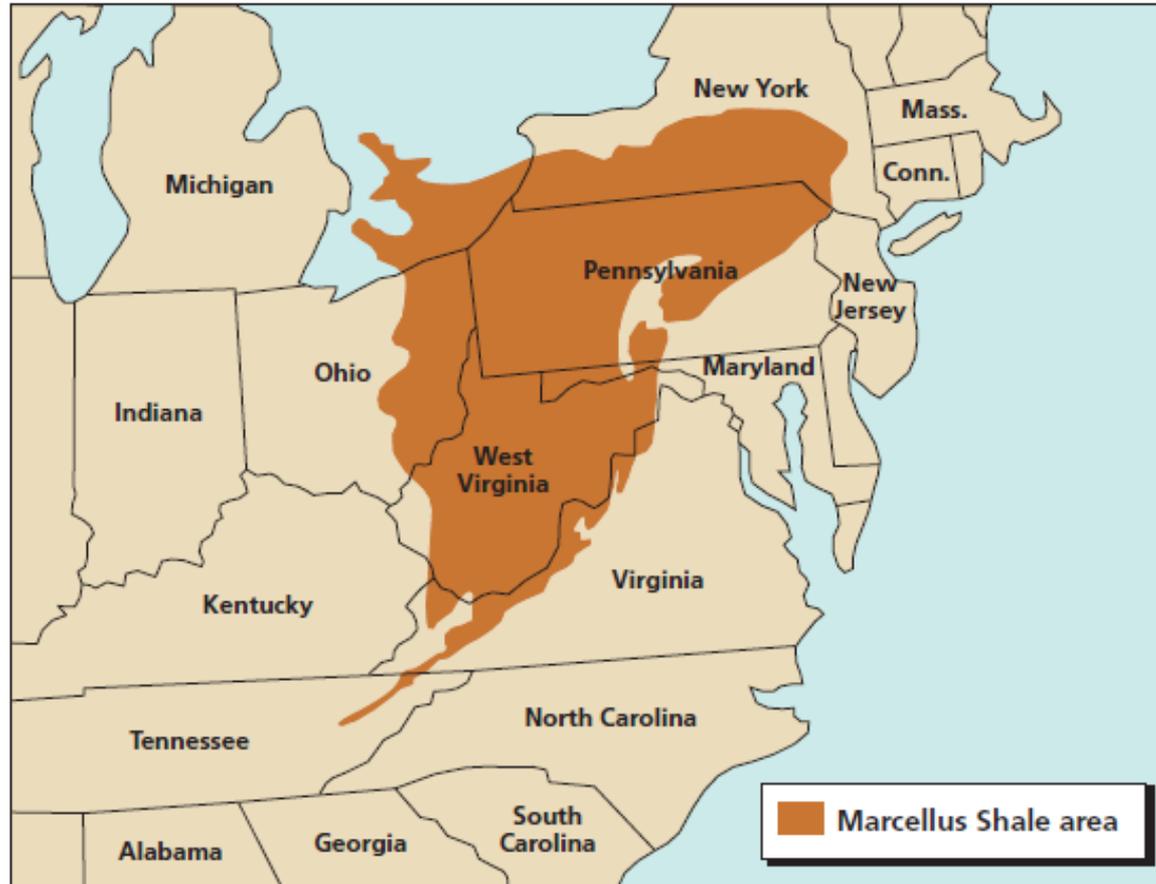
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Shale Gas Resources Have Changed the Energy Outlook in the U.S. and Canada

- **Natural gas is a versatile fuel, used to:**
 - **Produce electricity**
 - **Provide residential and commercial heating**
 - **Generate industrial process steam and heat**
- **Natural gas is relatively clean burning**
 - **Low criteria pollutants**
 - **Half the greenhouse-gas intensity of coal**
- **The N. American natural gas outlook has changed dramatically due to unconventional resources, such as gas trapped in shale deposits**

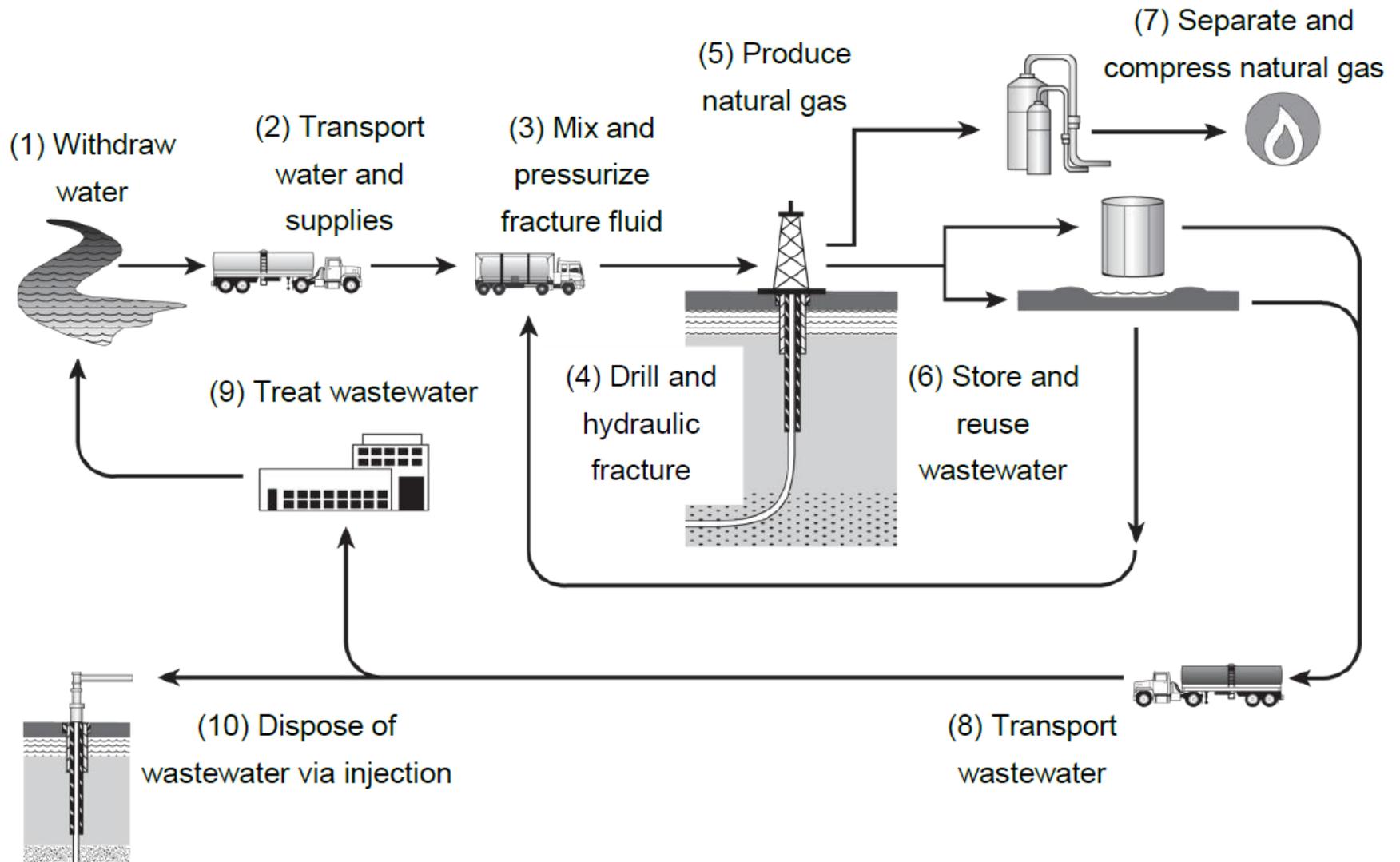
The Marcellus Shale Formation is a Major Natural Gas Resource for the United States



SOURCE: Adapted from U.S. Geological Survey.

Technically recoverable reserves: ~140 trillion cubic feet (Tcf)

Schematic of the Major Steps of Shale Gas Extraction Considered in Our Analysis



Extracting and Using Natural Gas from Shale Has Regional and Local Policy Implications

- Shale gas provides benefits
 - Lower energy costs
 - Direct and indirect economic activity and jobs
 - Wealth generation for individuals
 - Tax and impact fee revenue
 - Reductions in electricity emissions (vs. coal)
- Shale gas extraction also imposes external costs
- Impact fees can be used to reduce external costs and can generate revenue

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Our analysis focused on external costs important to regional and local stakeholders in Pennsylvania

There Are A Range of Potentially Significant External Costs from Shale Gas Extraction

- **Water use and water pollution**
- **Air pollution**
- **Infrastructure damage**
- **Adverse community impacts**
- **Damage to ecosystems and agriculture**
- **Also leads to increased demands on public services, regulatory agencies**

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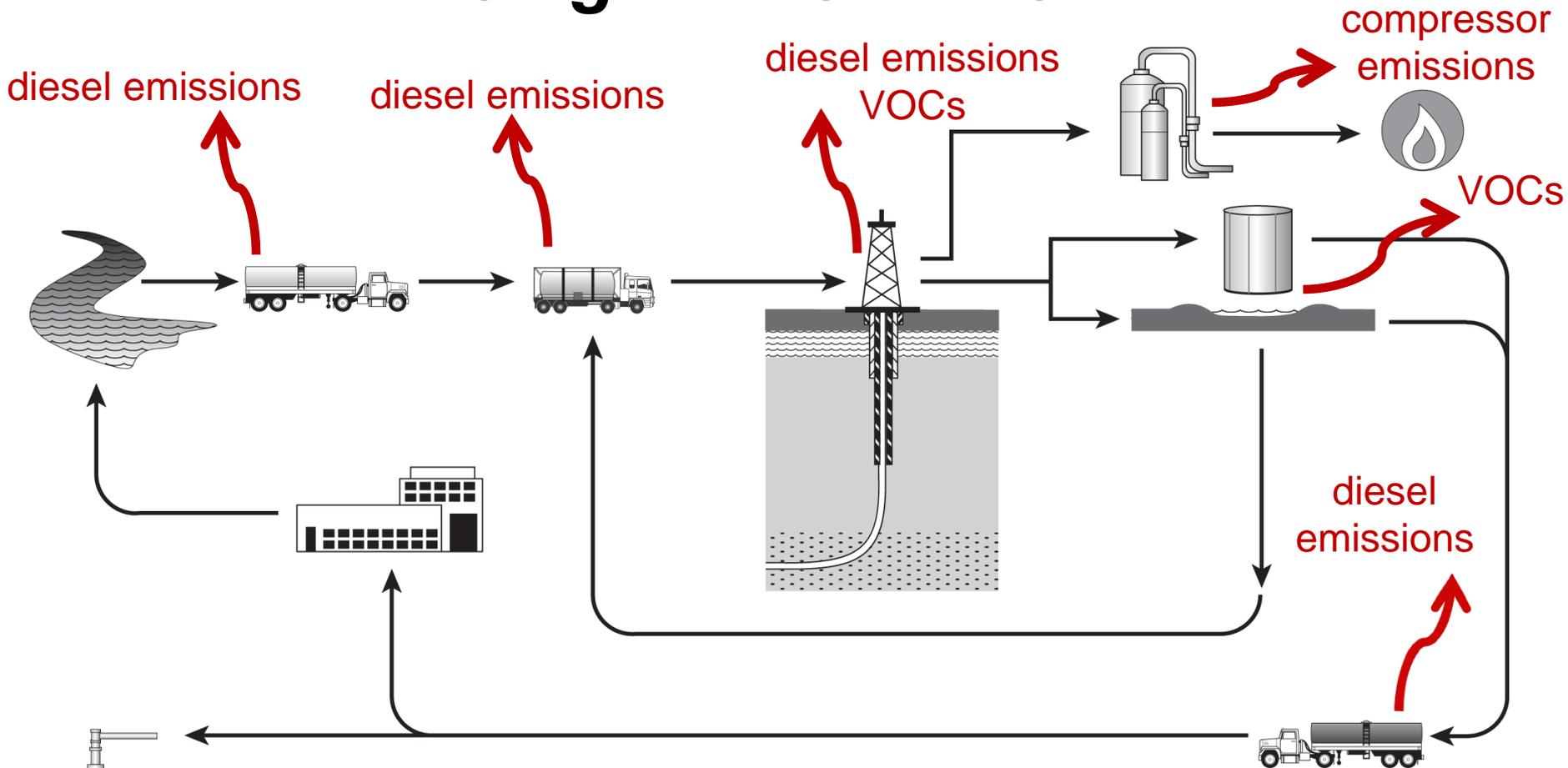
RAND Assessed the External Costs of Shale Gas Extraction in Pennsylvania

- **Identified categories of risks**
- **Assessed the (relative) magnitude and likelihood of each risk**
- **When possible, estimated the monetized cost of each risk**

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Conventional Air Pollutants Are Emitted Across Most Stages of Shale Gas Production



*“Estimation of regional air-quality damages from Marcellus Shale natural gas extraction in Pennsylvania”, Litovitz *et al* 2013 *Environ. Res. Lett.* 8 014017

Emissions Can Impact Local and Regional Air Quality, With Health Implications

- **Types and sources of pollutants include**
 - **VOCs: diesel combustion; venting and flaring; leaks/spills**
 - **NO_x: diesel and natural gas combustion**
 - **PM_{2.5}, PM₁₀: diesel combustion; road dust; reaction of SO₂ (indirect)**
 - **SO₂: diesel combustion**
 - **O₃: reaction of NO_x and VOCs (indirect)**
- **Damages include**
 - **Adverse respiratory effects, reduced lung function, aggravation of heart disease, premature death**
 - **Increased illness and hospital admissions**
 - **Infrastructure, ecosystem/agriculture, aesthetic impacts**

We Estimated Air Emissions and Associated Health and Environmental Damages

- **Estimates included 4 major activities**
 1. **Transport**
 2. **Well drilling and hydraulic fracturing**
 3. **Natural gas production**
 4. **Compressor stations**
- **Sources of emissions estimates were**
 - **Published literature**
 - **Industry reports to PA DEP**
 - **PA DEP permit applications**
- **Emissions were translated into damages**
 - **County-specific emissions were calculated**
 - **Regional damages compared to other sectors**

In 2011, Regional Damages from Extraction Industry Emissions Were Millions of Dollars

Table 6. Estimates of Regional Air Pollution Damages from Pennsylvania Extraction Activities in 2011

Activities	Timeframe/ Boundaries	Total Regional Damage for 2011 (\$2011)	Average Per Well or Per MMCF Damage (\$2011)
1. Transport to and from Well-Site	Development	\$320,000 - \$810,000	\$180 - \$460 per well
2. Well Drilling, Hydraulic Fracturing	Development	\$2,200,000- \$4,700,000	\$1,200 – \$2,700 per well
3. Production	Ongoing	\$290,000-\$2,700,000	\$0.27 – \$2.60 per MMCF
4. Compressor Stations	Ongoing	\$4,400,000 - \$24,000,000	\$4.20 - \$23.00 per MMCF
1-4. Aggregated	Development and Ongoing	\$7,200,000 - \$32,000,000	NA

- *Approximate per-well damages: ~\$4,000 to 18,000*

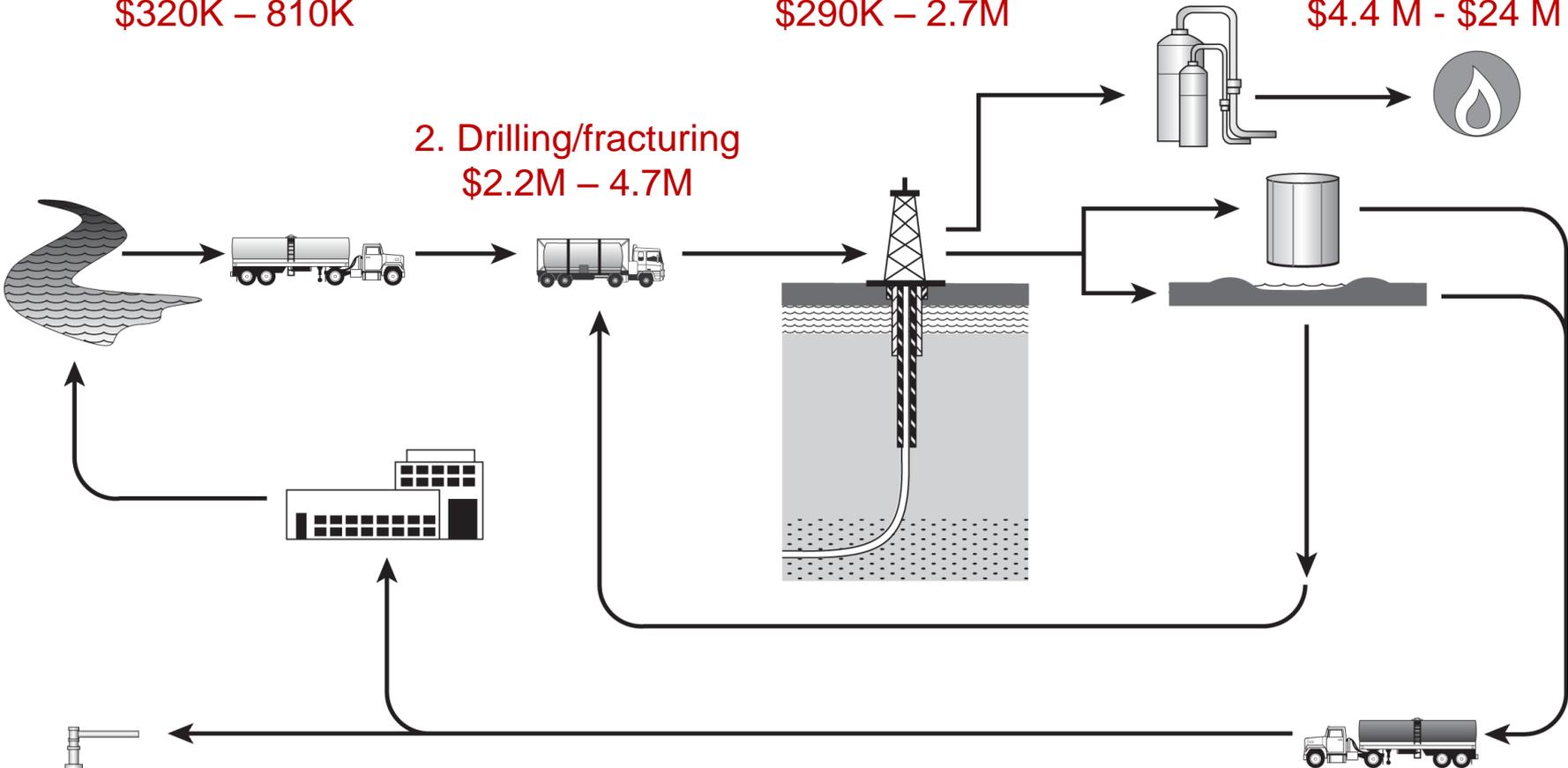
Sources and Statewide Magnitude of Damages

1. Transport
\$320K – 810K

3. Production
\$290K – 2.7M

4. Compressors
\$4.4 M - \$24 M

2. Drilling/fracturing
\$2.2M – 4.7M



- 94% of damages due to VOCs, NO_x, and PM_{2.5}

Overall Emissions Damages Are Relatively Small ... But of Concern in Some Locations

Table 7. Magnitude of Shale Gas Extraction Industry Relative to Air Pollutant Emissions from Other Industrial Sectors in Pennsylvania

Total Sector or Comparison	VOCs	NO_x	PM_{2.5}	PM₁₀	SO_x
Shale gas extraction industry in 2011, from Table 5 (metric tons)	2,500 – 11,000	17,000 – 28,000	460 – 1,400	460 – 1,400	12 – 540
Total, all sectors reporting (metric tons) ¹	720,000	579,000	134,000	322,000	898,000
Shale extraction relative to total (percent)	0.35 – 1.5%	2.9 – 4.8%	0.34 – 1.0%	0.14 – 0.43 %	0.0013 – 0.060%

- *Statewide VOC and NO_x on par with largest coal plants*

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- *>20% of wells in one county, ~90% in 10 counties*
- *Most active counties: 20-40 times the “major” source threshold*

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- *Statewide VOC and NO_x on par with largest coal plants*
- *>20% of wells in one county, ~90% in 10 counties*
- *Most active counties: 20-40 times the “major” source threshold*
- *Largest damage attributable to one county: \$1.2 to 8.3 million... where nearby population is larger, baseline air quality is worse*

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Context of Act 13, PA's Impact Fee Legislation

- **Impact fee is specifically intended for costs of impacts to state and municipalities**
- **Fees are imposed on a per-well basis for a finite period of time, scale with the price of natural gas**
- **Counties where drilling occurs make the individual decision to opt in**
 - **Fee only collected, and revenue only distributed, in counties that opt in**
 - **Non-drilling counties will not directly benefit**

Problems May Exist with Impact Fee Rate, Use Restrictions, and Transboundary Costs

- **Optimal fee (Pigovian tax) should be set equal to marginal social damage, but damages are often difficult to estimate**
- **Revenue use is restricted, may not be properly aligned with impacts or allocated to optimal uses**
- **Potential external costs may extend beyond county and municipality boundaries set in Act 13**

Problems with Magnitude, Alignment in the Major Risks We Studied in Detail

- **Fee ranges from \$5K to \$60K per well per year**
- **Emissions damages are \$4K - \$18K on per-well basis, with up to 80% persisting beyond sunset of fee collection**
- **Fee revenue accrues directly to drilling counties only, with some revenue to state**
- **Some damages (e.g., air emissions) are a regional issue**

Air Emissions Are a Cost of Shale Gas Extraction But Can Be Reduced

- **Under current practices, emissions from diesel and natural gas combustion are guaranteed**
- **Long-term emissions dominate; most not at the shale-extraction site and not related to “unconventional” nature of resource**
- **Changes in regulatory framework may be appropriate**
 - **Improvements in technology can reduce emissions (e.g., green completions, BACT)**
 - **Aggregation may (or may not) be appropriate**
- **Uncertainty in estimates is high, further study is warranted**

Relevant Policy Changes for Pennsylvania

- **Jan 31, 2013: PA DEP releases revised GP-5 General Operating Permit for NG compression/processing facilities**
- **Feb 12: PA DEP officially releases unconventional drilling industry inventory**
- **Feb 20: EPA's Office of Inspector General releases report on improving air emissions data for oil and gas sectors**

What about Liquefied Natural Gas (LNG)?



What about Liquefied Natural Gas (LNG)?

Will LNG industry increase air pollution in northern B.C.?

The Canadian Press Posted: Nov 22, 2013 7:41 AM PT | Last Updated: Nov 22, 2013 7:41 AM PT



The B.C. government has touted its plans to build LNG refineries and produce the world's cleanest natural gas, but a new report by environmental group Tides Canada questions whether B.C. is embracing the newest technologies that will lower greenhouse gas emissions from new LNG plants. (CBC)



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A northwest B.C. environmental organization concerned about the area's wild salmon ecosystem has released a report that estimates three proposed Kitimat LNG plants will burn 2.5 times more natural gas than is consumed in Metro Vancouver annually.

The SkeenaWild Conservation Trust report, "Air Advisory: The Air Quality Impacts of Liquefied Natural Gas Operations Proposed for Kitimat, B.C.," concluded LNG plants permitted to operate primarily with natural gas will

Port Metro Vancouver mediator Vince Res

LNG Facility Will Increase Emissions but Location and Baseline Air-Quality Matter

- **Kitimat plant in British Columbia**
 - **5 million metric tons LNG per year initially**
 - **10+ mmt expansion capacity**
- **Net emissions effecting air quality will increase¹**
 - ***Lifecycle* SO_x and NO_x are 2-3xs greater for LNG than conventional NG**
 - **Same emissions in use; large benefit relative to coal, especially in SO_x**
- **BC-govt is funding a study on air-quality impacts**

¹Jaramillo, Griffin, & Matthews. *Environ. Sci. Technol.*, 2007, 41 (17), pp 6290–6296

²<http://boereport.com/oil-and-gas-news-headlines/news/b-c-government-announces-study-on-impact-of-lng-emissions/>



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Problems with Magnitude, Alignment in the Major Risks We Studied in Detail

- **Fee ranges from \$5K to \$60K per well per year**
 - Road damages may be \$5K - \$23K per well, although damages drop off after first year
 - **Emissions damages are \$4K - \$18K on per-well basis, with up to 80% persisting beyond sunset of fee collection**
- **Fee revenue accrues directly to drilling counties only, with some revenue to state**
 - Statewide agencies (PennDOT, PA DEP) may not be fully compensated for costs
 - **Some damages (e.g., air emissions) are a regional issue**

Additional Emissions Also Associated with a Chemical Facility (e.g., Ethane Cracker)

- See <http://www.alleghenyfront.org/ChemicalBoom>