Air Impacts of Shale Gas Extraction and Distribution

Chris Moore, PhD
Desert Research Institute
Division of Atmospheric Science,
Reno, NV

May 30, 2013

Outline

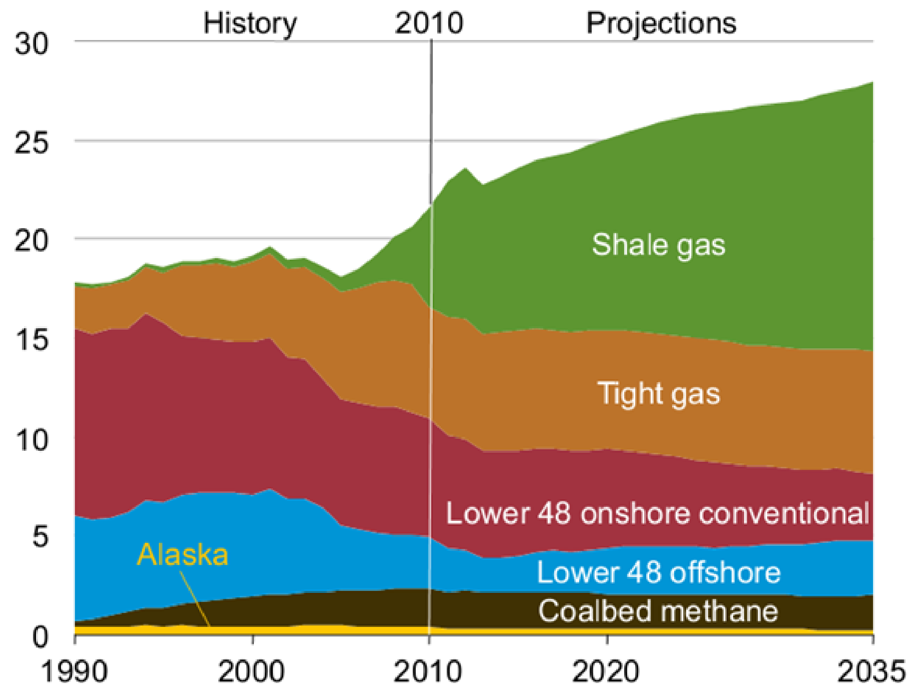
- Objective
- Introduction
- Well Development
- Production
- Distribution and Storage
- Conclusions

Objective

- Summarize existing and available data on air impacts of shale gas extraction and distribution for each compartment of the shale gas life cycle
- Address areas where data may be lacking

Introduction

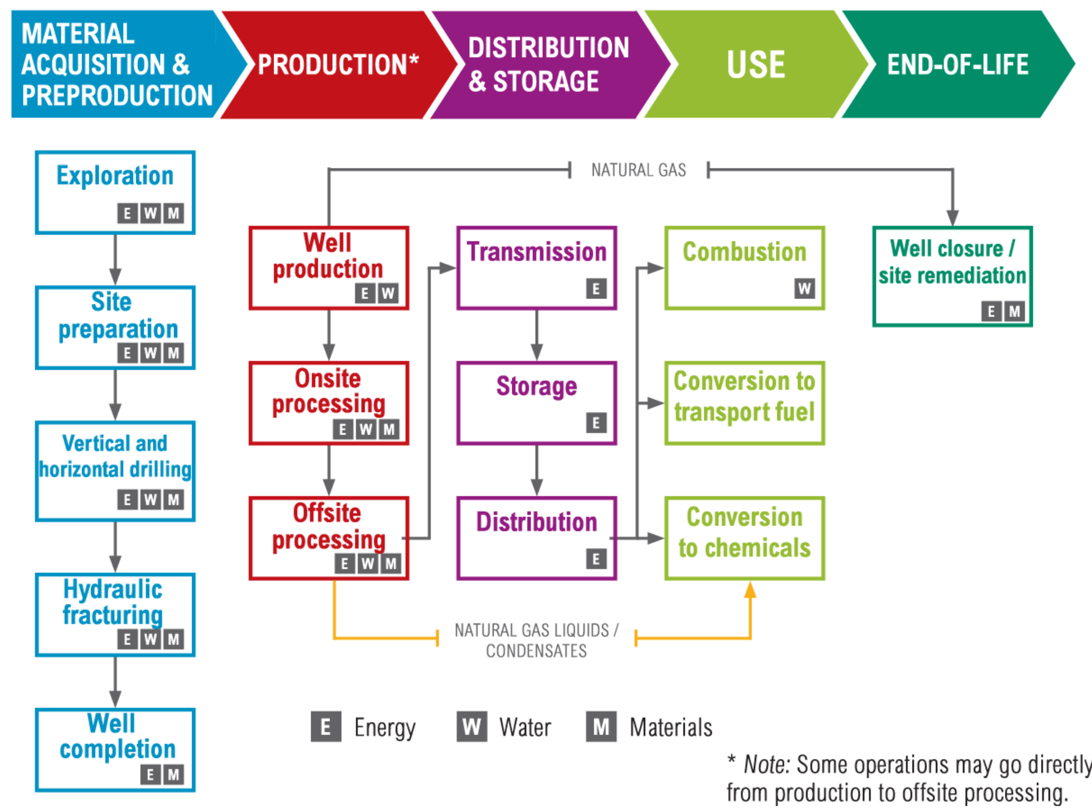
- Shale gas development expected to increase steadily over next 20 years
- Led by recent improvements in drilling and hydraulic fracturing



From USEIA (2012)

Introduction – Life Cycle

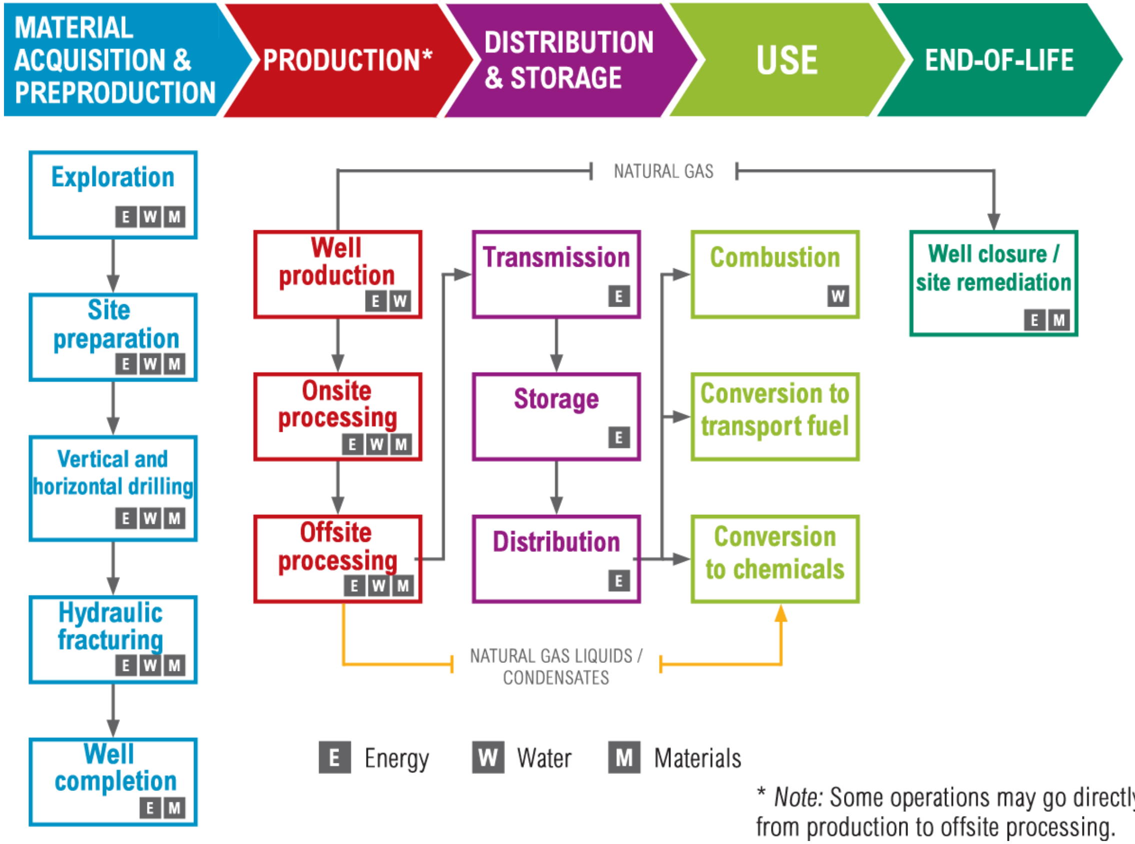
- Life cycle of shale gas
- Hydraulic fracturing only a small part of the overall life cycle
- Single well can span 30 – 50 years



Branosky et al. (2012)

Desert Research Institute

Introduction – Life Cycle



Branosky et al. (2012)

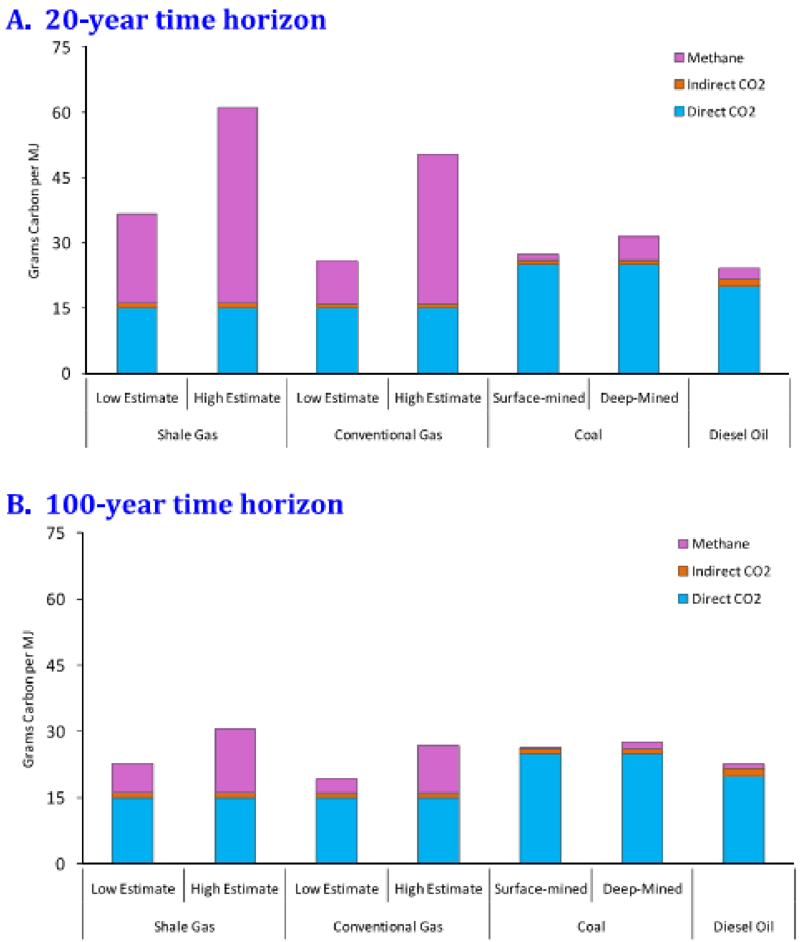
Desert Research Institute

Introduction - Emissions

- Methane and Ethane
- BTEX (Benzene, Toluene, Ethylbenzene and Xylenes)
- Hydrogen Sulfide
- Ozone precursors (NOx and non-methane VOCs)
- Particulate matter
- Silica

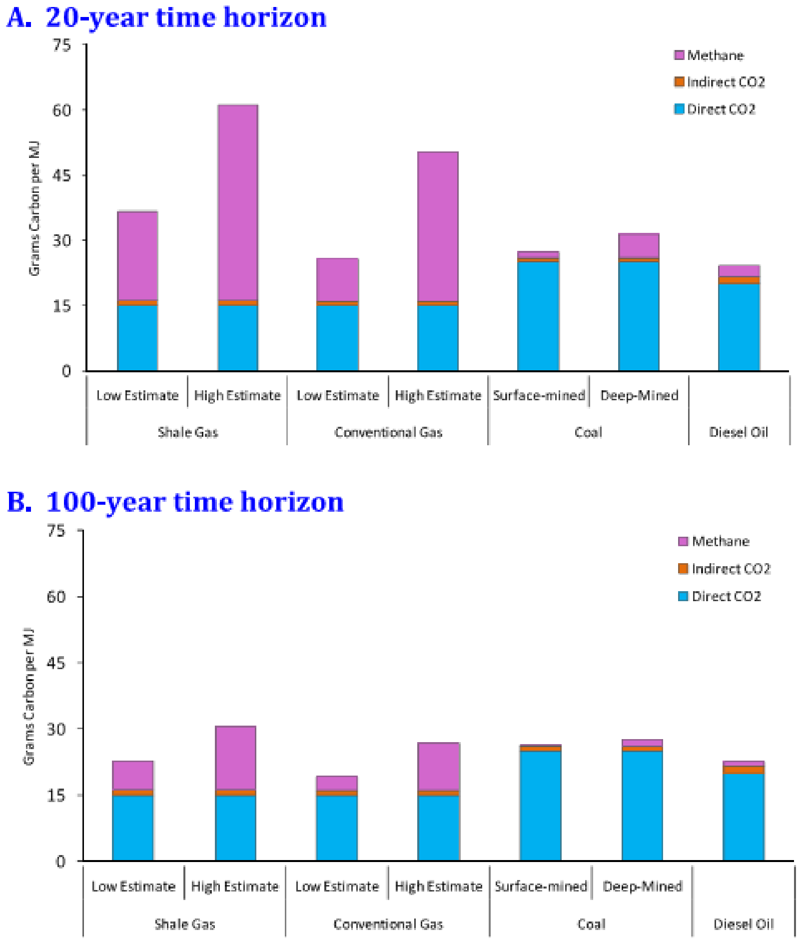
Introduction - Emissions

- Shale gas is projected to have similar GHG emissions to Coal and Conventional Gas



From Howarth et al. (2011)

Introduction - Emissions



Howarth et al. (2011)

Introduction - Uncertainty

- Methane emissions have been recalculated
  - Up to 33% annual decrease
- Difference highlights uncertainties

2012 EPA estimated CH4 emissions from Natural Gas Systems (Tg CO_2 Eq.)

Stage	1990	2005	2006	2007	2008	2009	2010
Field Production	89.0	105.2	133.8	117.8	123.2	129.4	126.0
Processing	18.0	14.6	14.8	15.5	16.2	17.8	17.1
Transmission and Storage	49.2	41.4	40.9	42.5	43.3	44.7	438
Distribution	33.4	29.3	28.3	29.4	29.9	29.1	28.5
Total	**189.6**	**190.5**	**217.8**	**205.2**	**212.6**	**221.0**	**215.4**

2013 EPA estimated CH4 emissions from Natural Gas Systems (Tg CO_2 Eq.)

Stage	1990	2005	2007	2008	2009	2010	2011
Field Production	60.8	75.5	83.1	76.4	61.9	57.2	53.4
Processing	17.9	14.2	15.2	15.9	17.5	16.5	19.6
Transmission and Storag	49.2	39.5	40.8	41.2	42.4	41.6	43.8
Distribution	33.4	29.8	29.3	29.9	28.9	28.3	27.9
Total	**161.3**	**159.0**	**168.4**	**163.4**	**150.7**	**143.6**	**144.7**
Difference	-15%	-17%	-18%	-23%	-32%	-33%	

From USEPA (2012) and USEPA (2013)

DRI Desert Research Institute

Introduction - Uncertainty

2012 EPA estimated CH4 emissions from Natural Gas Systems (Tg CO_2 Eq.)

Stage	1990	2005	2006	2007	2008	2009	2010
Field Production	89.0	105.2	133.8	117.8	123.2	129.4	126.0
Processing	18.0	14.6	14.8	15.5	16.2	17.8	17.1
Transmission and Storage	49.2	41.4	40.9	42.5	43.3	44.7	438
Distribution	33.4	29.3	28.3	29.4	29.9	29.1	28.5
Total	**189.6**	**190.5**	**217.8**	**205.2**	**212.6**	**221.0**	**215.4**

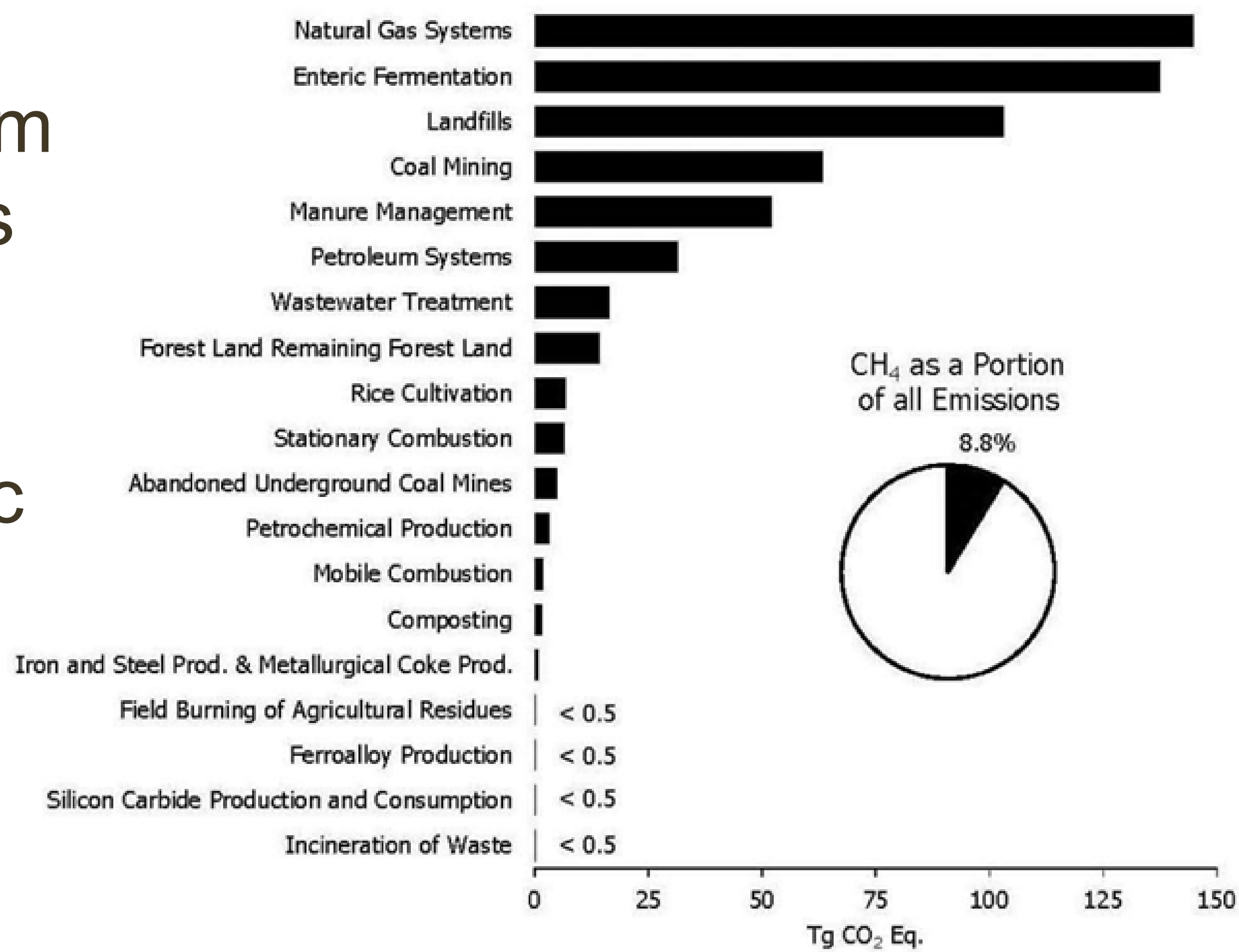
2013 EPA estimated CH4 emissions from Natural Gas Systems (Tg CO_2 Eq.)

Stage	1990	2005	2007	2008	2009	2010	2011
Field Production	60.8	75.5	83.1	76.4	61.9	57.2	53.4
Processing	17.9	14.2	15.2	15.9	17.5	16.5	19.6
Transmission and Storag	49.2	39.5	40.8	41.2	42.4	41.6	43.8
Distribution	33.4	29.8	29.3	29.9	28.9	28.3	27.9
Total	**161.3**	**159.0**	**168.4**	**163.4**	**150.7**	**143.6**	**144.7**
Difference	-15%	-17%	-18%	-23%	-32%	-33%	

From USEPA (2012) and USEPA (2013)

Introduction - Methane

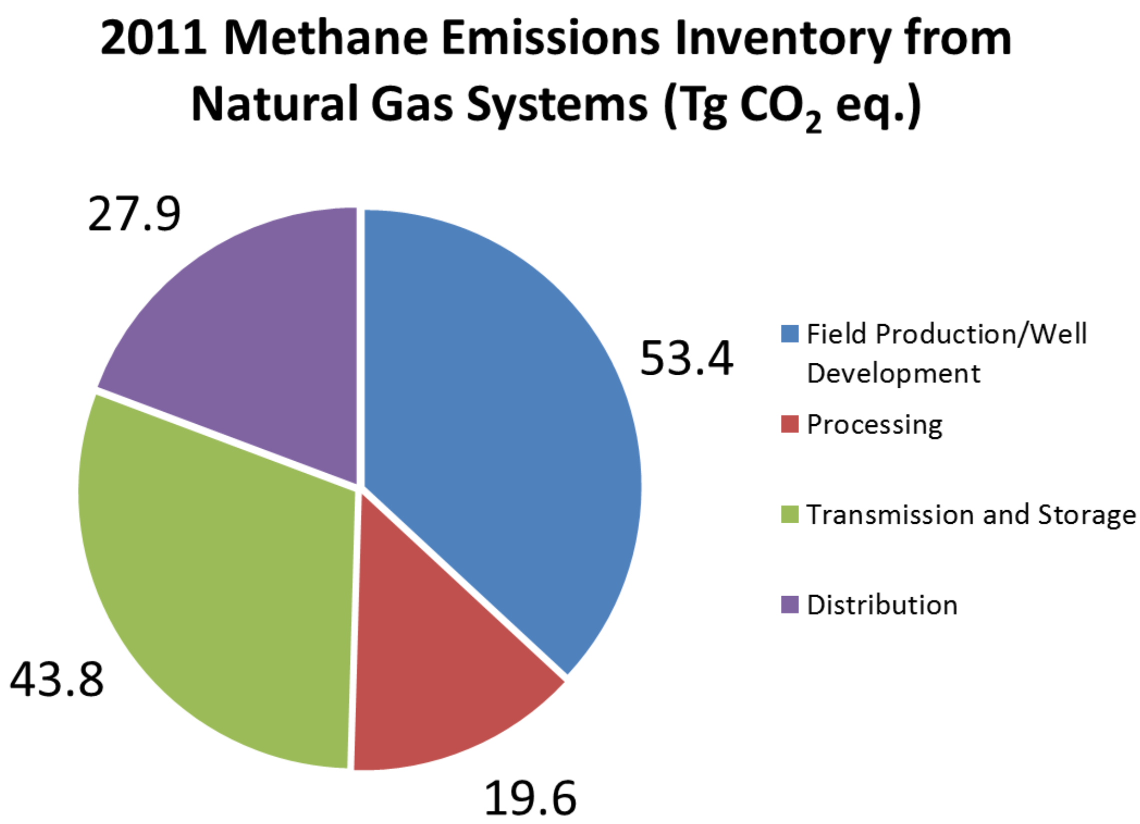
- Methane emissions from all natural gas systems highest anthropogenic input in U.S.



From USEPA (2013)

Introduction – Life Cycle Methane

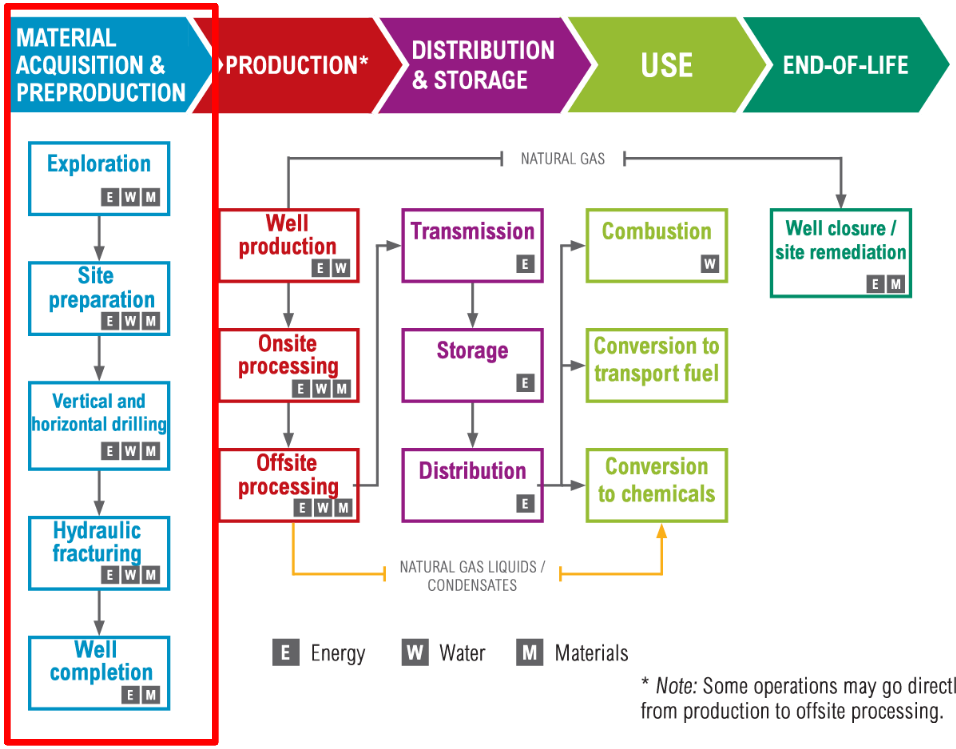
- Highest methane emissions during field production



From USEPA (2013)

Life Cycle Segments

Well Development



Branosky et al. (2012)

Desert Research Institute

Site Preparation

- Heavy equipment is used to create roads and clear/prepare well pad site
- Generators are set up
- Emissions
  - Vehicle emissions – particularly diesel
  - Coarse particulate matter increases due to increased dust from higher traffic on roads

Photos from http://joyce-road.blogspot.com/

Drilling and Hydraulic Fracturing

- 1 – 5 million gallons of water hauled
- Fracking fluid and Frac Sand are used to open cracks in rock to give the gas a pathway to flow
- Emissions
  - Hydrogen Sulfide
  - Methane
  - Diesel vehicle emissions
  - Particulate matter
  - Silica

Well Sites

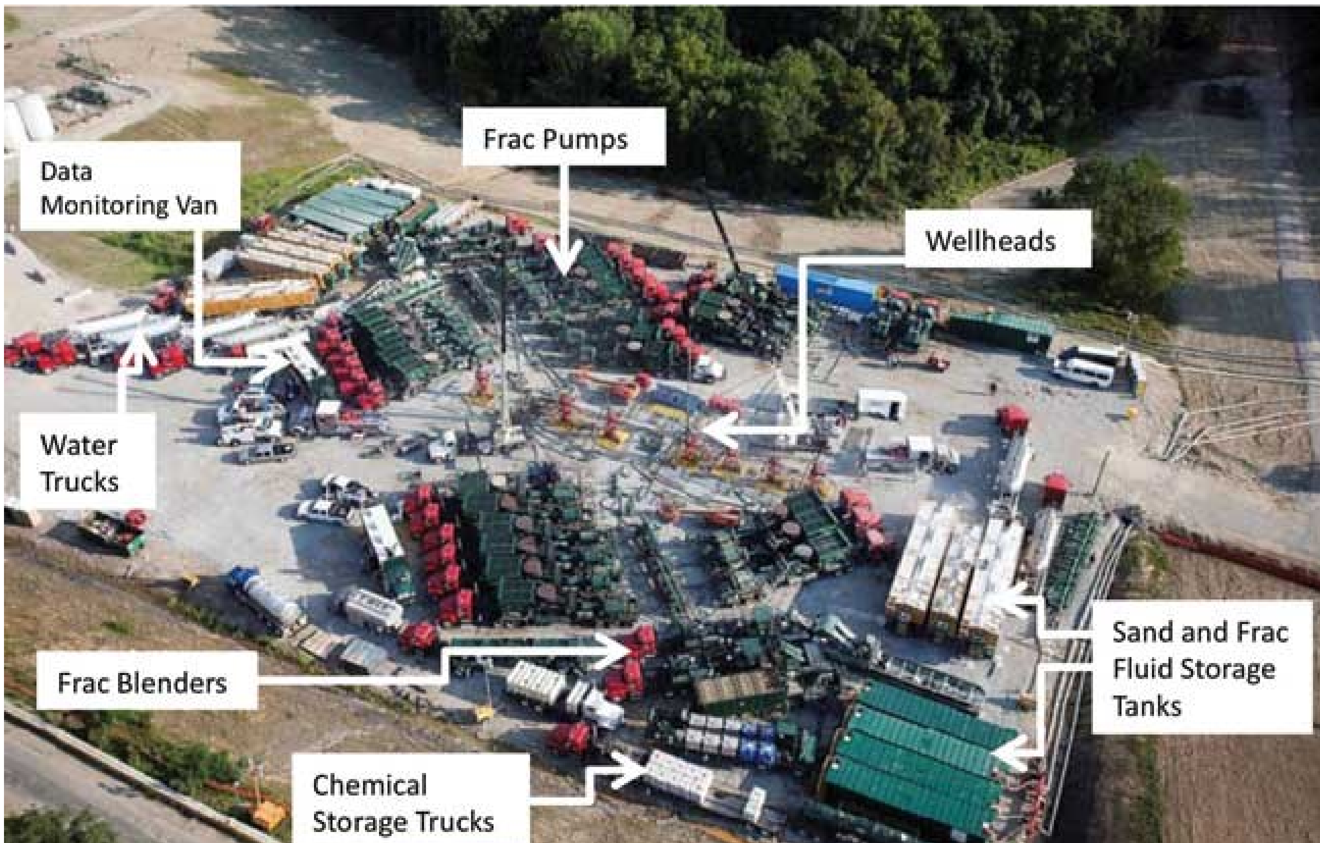


Photo from Suchy and Newell, Kansas Geological Survey

Photo from Pennsylvania Independent Oil and Gas Association

Well Completion

- Flowback
- Liquids unloading
  - Process where liquid is removed from the well bore and natural gas begins flowing
- Venting and flaring
- Emissions
  - Methane
  - Hydrogen sulfide
  - VOCs (including BTEX)


Carolyn Cole/Los Angeles Times/MCT


circle of blue
http://www.circleofblue.org

Desert Research Institute

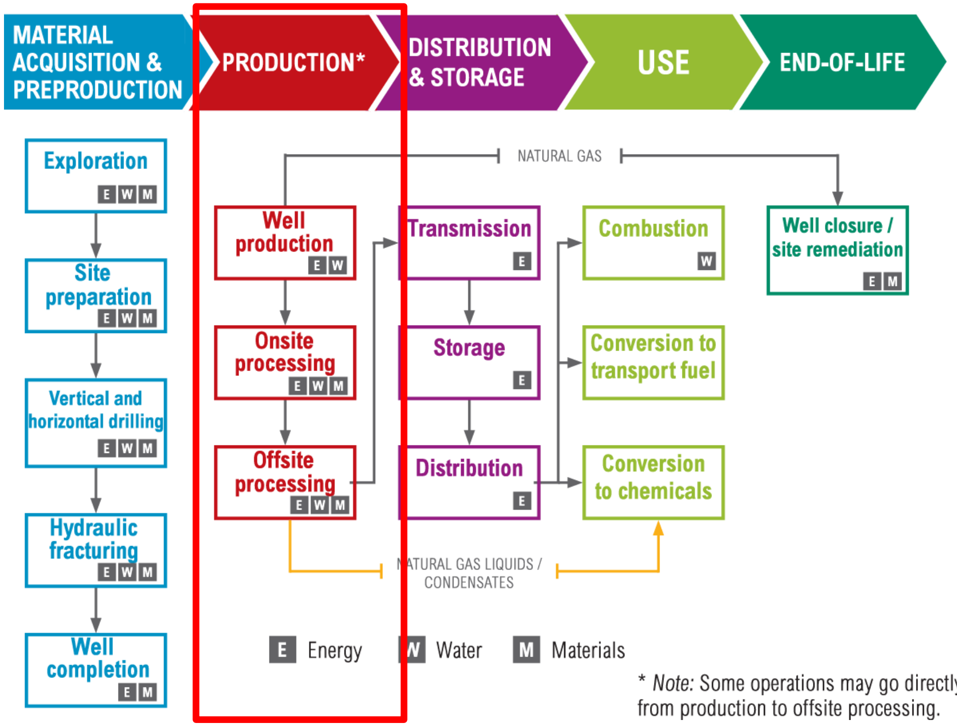
Case Study – Garfield County, CO

- Rural area 250 km west of Denver, CO
- Collected samples from January 2008 to November 2010 with fixed monitoring stations
- Sampled around well completion activities at 4 well pads in summer 2008 and one in summer 2010
- Evaluated risks for residents within 0.5 mile and beyond 0.5 mile from well
- Found enhanced health risks for residents living closer to well sites
- McKenzie et al. (2012) *Science of the Total Environment*

Other Studies

- ERG-Sage (2011)
  - City of Fort Worth Natural Gas Air Quality Study conducted for 2 months at eight sites
  - No pollutants including 59 VOCs, 11 carbonyls, and methane were found to exceed Texas air quality limits
  - 600 foot setback distances adequately protect public health
- Rodriguez and Ouyang (2013)
  - Master's thesis on air emissions from engines during hydraulic fracturing
  - Frack pump engines responsible for 83% of all equipment emissions during hydraulic fracturing operations

Production



Branosky et al. (2012)

Well Production

- Compressors and pumps used to bring produced gas up to surface and up to pipeline pressure
- Emissions
  - Methane
  - VOCs

On Site Processing

- Oil and water must be removed from the natural gas before entering pipelines
- Condensate tanks, separators and dehydrators are used
- Gas must be compressed and pushed through pipelines
- Emissions
  - Methane
  - Diesel / compressor emissions
  - VOCs (including BTEX)

Off Site Processing

- Gas is further pressurized for longer transport via large compressor stations
- Emissions
  - Diesel and compressor emissions
  - VOCs

Case Study – Barnett Shale

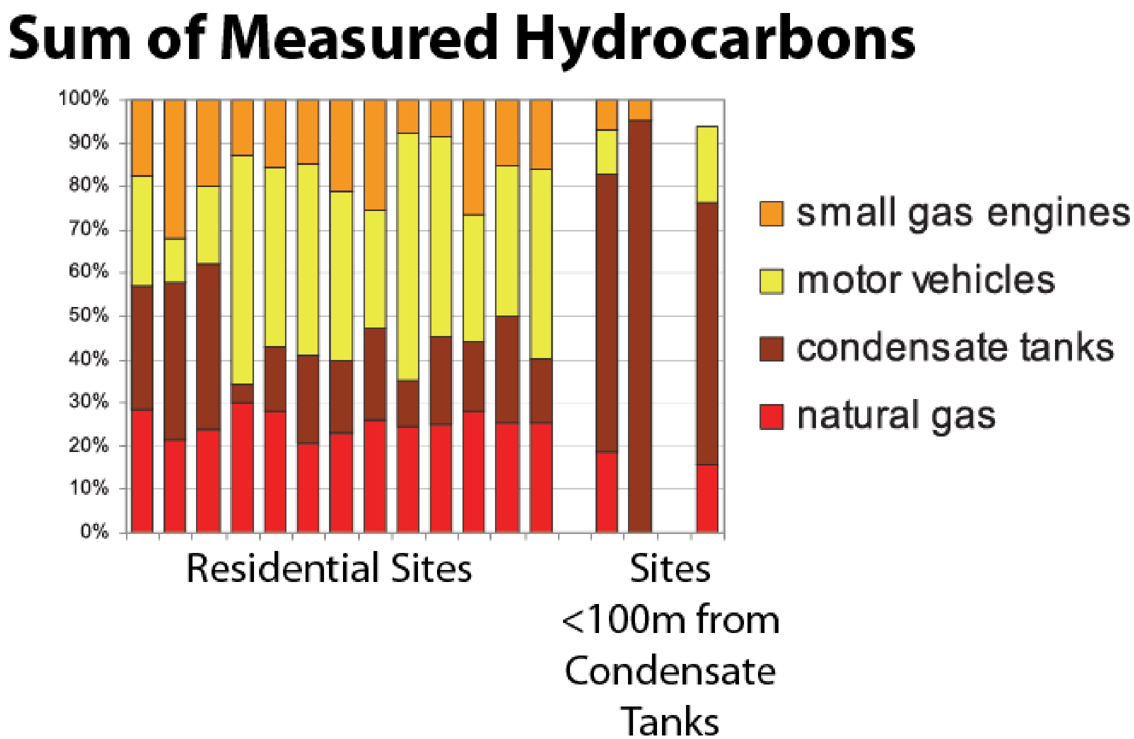
- Conducted in Wise County, TX (<100km northwest of Fort Worth)
- Included 2 preliminary phases
  - Phase I – emissions from nearby gas facilities characterized (mobile measurements April 2010)
  - Phase II – saturation monitoring (using passive VOC samplers) downwind of gas production areas (May 2010, one month)
- Main Conclusions
  - Main non-methane VOC emissions from condensate tanks were ethane, n-butane, iso-butane, iso-pentane, and n-pentane
  - BTEX only accounted for 0.1-0.2% of non-methane VOC emissions
  - Exponential decrease in downwind VOC concentrations with distance from well site and condensate tank emissions from tank vents due to dispersion
- Zielinska et al (2011)

Condensate Tanks and Compressors

Photo from Barbara Zielinska

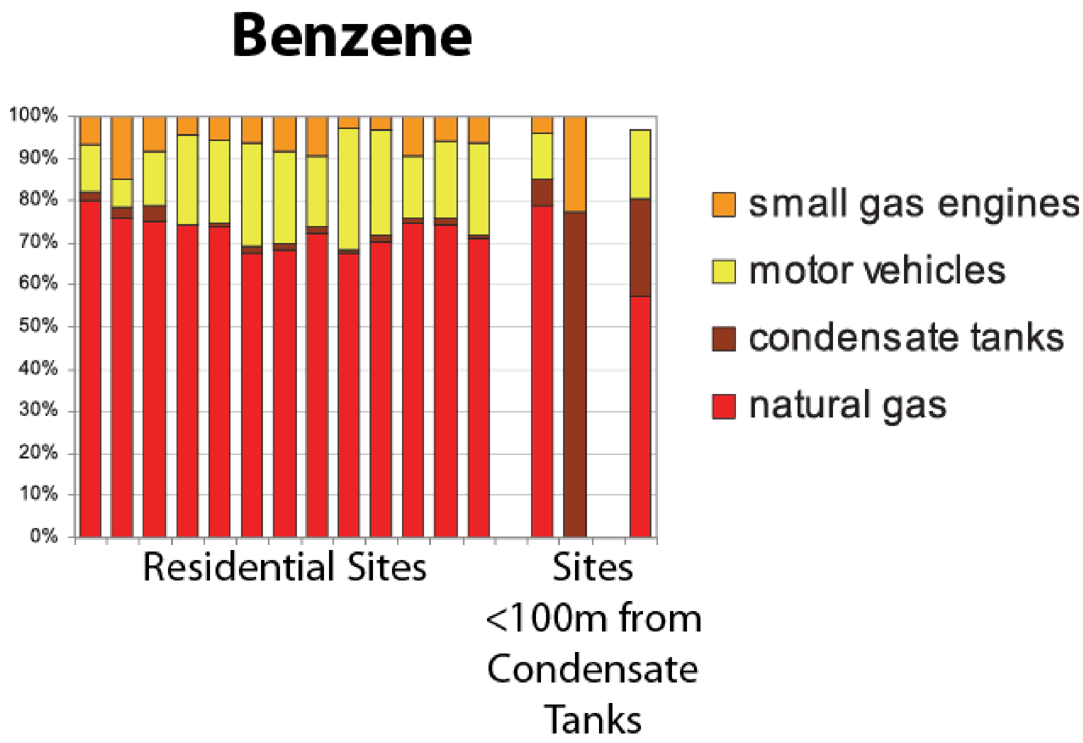
Desert Research Institute

Case Study – Barnett Shale



Zielinska et al. (2011)

Case Study – Barnett Shale



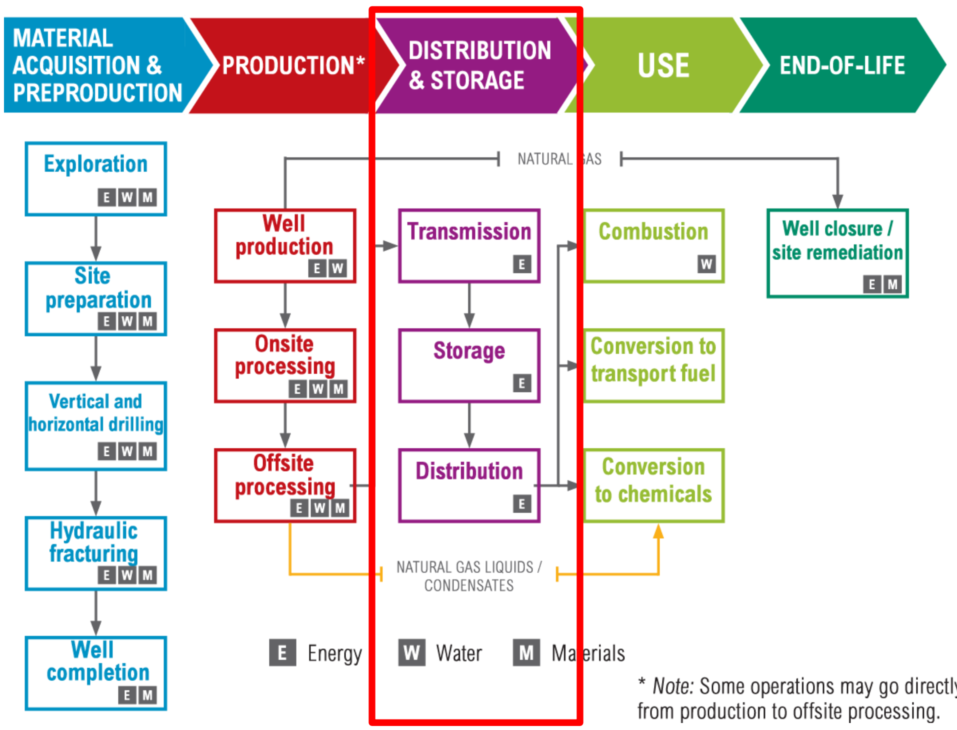
Zielinska et al. (2011)

Desert Research Institute

Other Studies

- Gilman et al. (2013)
  - 55 ± 18% of VOC-OH reactivity attributable to oil and natural gas production signatures in northeastern CO.
- Petron et al. (2012)
  - Methane emissions from the Denver-Julesburg Basin may be underestimated by a factor of 2
- Lyman and Shorthill (2013); Edwards et al. (2013)
  - Ozone linked to oil and natural gas fields in the Utah's Uintah basin is above EPA attainment levels even in winter
- Kemball-Cook et al. (2010)
  - If development continues in the Texas/Louisiana Haynesville Shale area even at a slow rate ozone will increase to above attainment levels
- TCEQ (2013)
  - Ongoing monitoring near natural gas facilities in Texas. Synthesis analysis forthcoming

Distribution and Storage



Branosky et al. (2012)

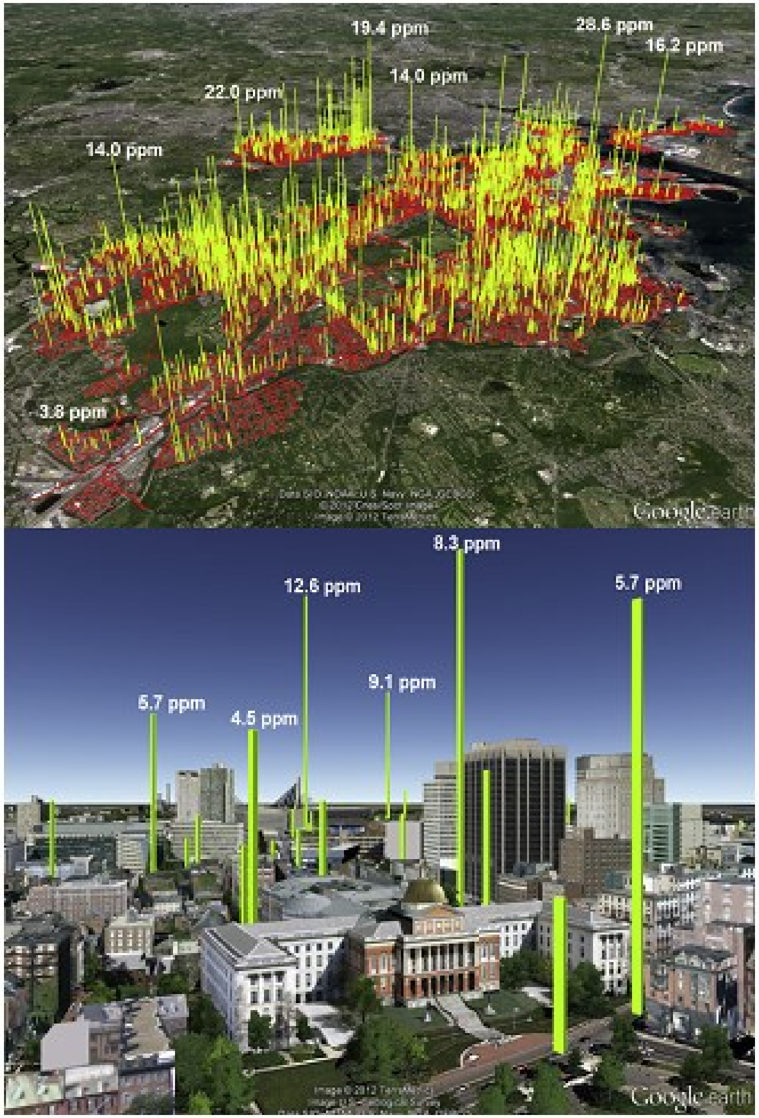
Transmission, Distribution and Storage

- Estimated $3.1 billion of natural gas lost annually in the U.S. through leaks (USEIA 2012).
- Valves and pipelines
- Compressor Stations
- Emissions
  - Methane
  - Ozone precursors

Case Study - Boston

- Mobile mapping of methane on all 785 road miles in Boston from August 18 – October 1, 2011
- Found 3356 methane leaks with direct link to natural gas
- Concentrations could exceed 15 times global background levels
- Phillips et al. (2013)

Case Study - Boston



Phillips et al. (2013)

Desert Research Institute

Conclusions

Conclusions

- Measurement data is critically lacking
- Targeted studies before, during and after drilling for all atmospheric constituents
- Determine emissions signatures from all shale gas formations/plays
- More data on surface atmosphere fluxes of methane and fugitive loss measurements in more urban areas
- Silica emissions characterization
- These steps must be taken to assure public safety in the near and distant future

Desert Research Institute

References

- USEIA (2012). Annual Energy Outlook 2012 with Projections to 2035, U.S. Department of Energy.
- Branosky, E., A. Stevens, et al. (2012). Defining the Shale Gas Life Cycle: A Framework for Identifying and Mitigating Environmental Impacts. Washington, D.C.
- Howarth, R. W., R. Santoro, et al. (2011). "Methane and the greenhouse-gas footprint of natural gas from shale formations." Climatic Change **106**(4): 679-690.
- USEPA (2012). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 - 2010.
- USEPA (2013). Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 - 2011.
- McKenzie, L. M., Witter, R. Z., Newman, L. S. & Adgate, J. L. Human health risk assessment of air emissions from development of unconventional natural gas resources. *Science of the Total Environment* **424**, 79-87, doi:10.1016/j.scitotenv.2012.02.018 (2012).

References

- ERG-Sage. City of Fort Worth Natural Gas Air Quality Study. http://fortworthtexas.gov/gaswells/default.aspx?id=87074., (2011).
- Zielinska, B., Fujita, E. & Campbell, D. Monitoring of Emissions from Barnett Shale Natural Gas Production Facilities for Population Exposure Assessment. Final Report to the National Urban Air Toxics Research Center. https://sph.uth.tmc.edu/mleland/attachments/DRI-Barnett%20Report%2019%20Final.pdf. (2011).
- Gilman, J. B., Lerner, B. M., Kuster, W. C. & de Gouw, J. A. Source Signature of Volatile Organic Compounds from Oil and Natural Gas Operations in Northeastern Colorado. *Environ Sci Technol* **47**, 1297-1305, doi:10.1021/Es304119a (2013).
- Petron, G. *et al.* Hydrocarbon emissions characterization in the Colorado Front Range: A pilot study. *Journal of Geophysical Research-Atmospheres* **117**, doi:10.1029/2011jd016360 (2012).

References

- Lyman, S. & Shorthill, H. 2012 Uintah Basin Winter Ozone and Air Quality Study. (2013).
- Edwards, P. M. *et al.* Ozone photochemistry in an oil and natural gas extraction region during winter: simulations of a snow-free season in the Uintah Basin, Utah. *Atmos. Chem. Phys. Discuss.* **13**, 7503-7552, doi:10.5194/acpd-13-7503-2013 (2013).
- Kemball-Cook, S. *et al.* Ozone Impacts of Natural Gas Development in the Haynesville Shale. *Environ Sci Technol* **44**, 9357-9363, doi:10.1021/Es1021137 (2010).
- TCEQ. *Sampling Results Near Oil and Natural Gas Facilities by County. http://www.tceq.texas.gov/toxicology/barnettshale/samplingresults. (*2013).
- Phillips, N. G. *et al.* Mapping urban pipeline leaks: Methane leaks across Boston. *Environmental Pollution* **173**, 1-4, doi:10.1016/j.envpol.2012.11.003 (2013).