WORKSHOP ON GOVERNANCE OF RISKS OF UNCONVENTIONAL SHALE GAS

National Research Council

August 15, 2013

Governance Considerations from a Technical Perspective

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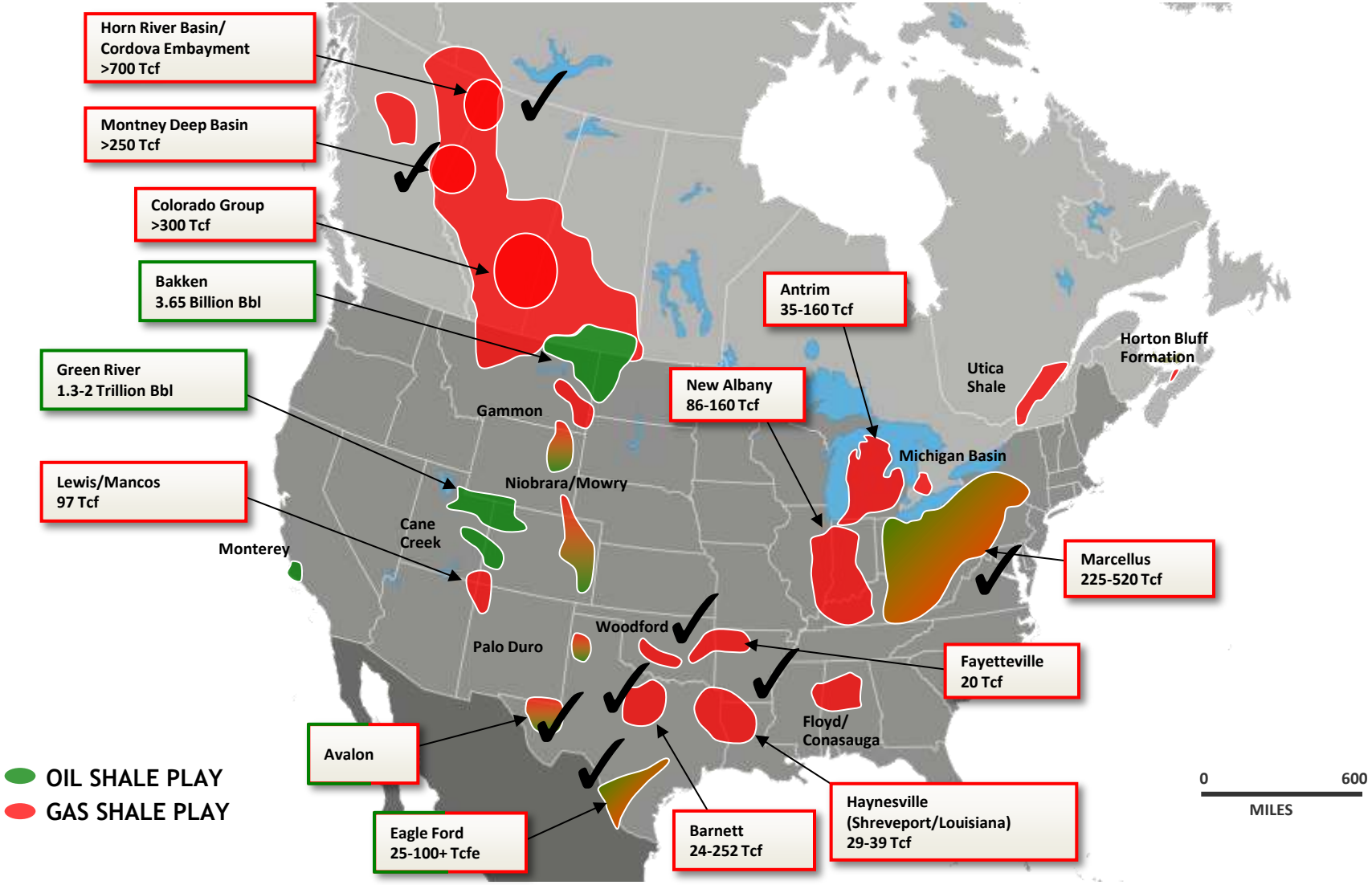
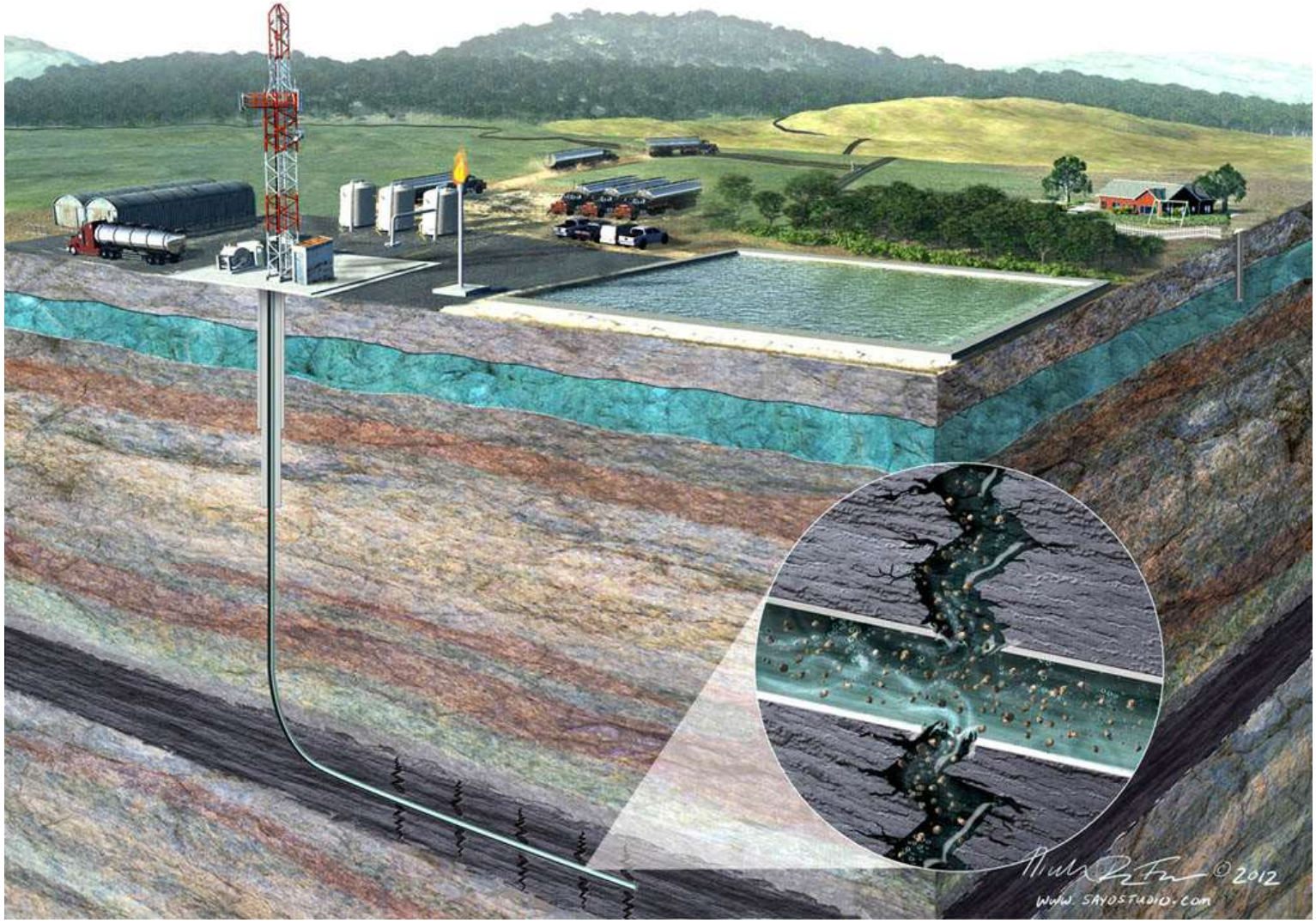
Shale Gas/Tight Oil Research Projects

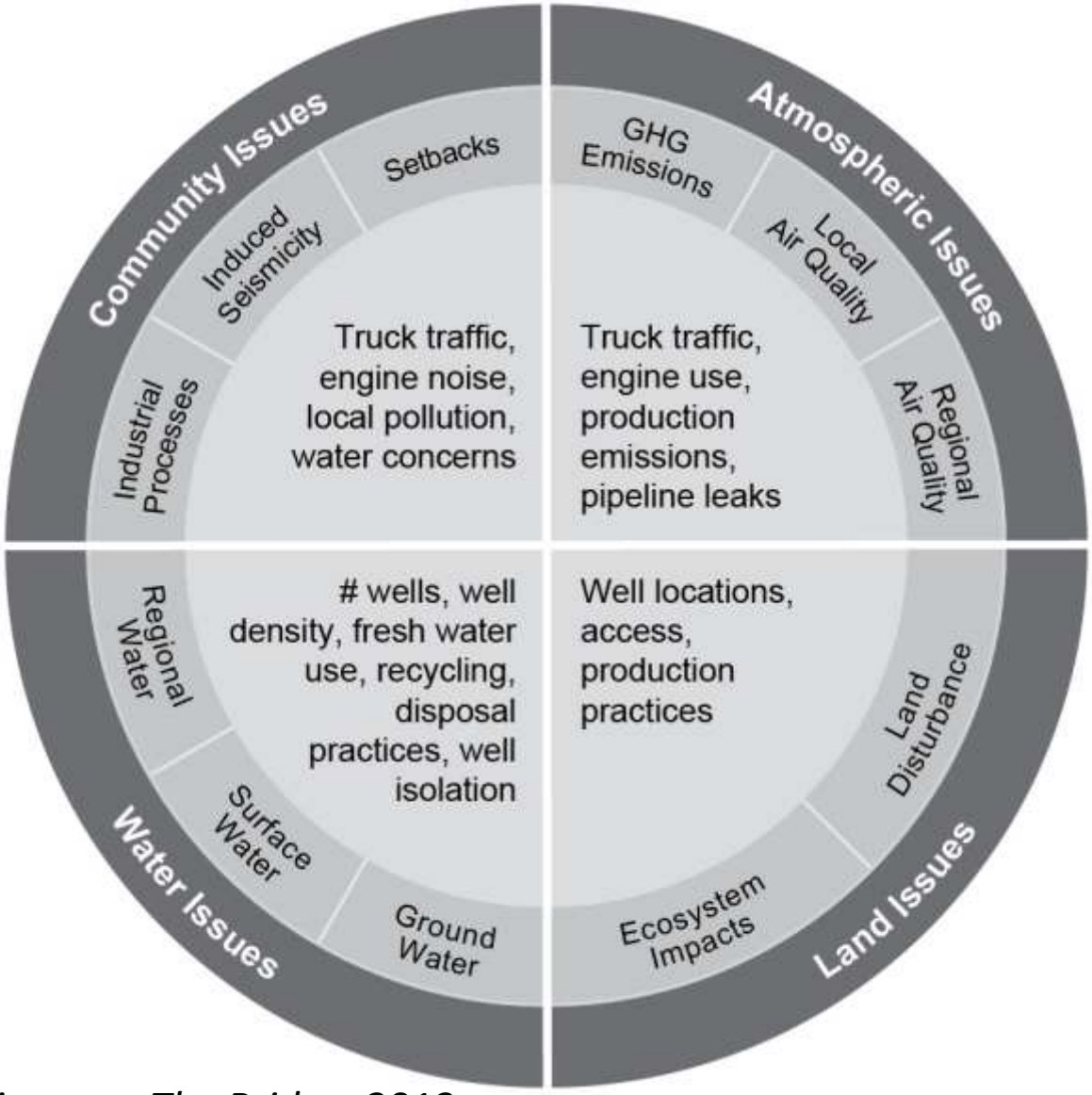


Minimizing the Environmental Impact of Shale Gas Development



Courtesy N.Fuller, SayoStudio.com

Governance Considerations from a Technical Perspective Are Multi-faceted



Zoback and Arent, in press *The Bridge*, 2013

Opportunities and Challenges of Shale Gas Development

- ***The proven ability to produce large quantities of natural gas from organic-rich shale formations has dramatically changed the energy picture in North America and has the potential to do so in many parts of the world.***
- ***There seems little question that rapid shale gas development coupled with fuel switching from coal to natural gas for power generation can have beneficial affects on air pollution, greenhouse gas emissions and enhanced energy security in many countries.***
- ***In this context, shale gas resources represent a critically-important transition fuel toward achieving a decarbonized energy future.***
- ***For these benefits to be realized, however, it is imperative that shale gas resources be developed with effective environmental safeguards to reduce its impact on land use, water resources, air quality and the communities impacted by development.***

Zoback and Arent, in press *The Bridge*, 2013

Governance Considerations from a Technical Perspective

- Review of Four SEAB Recommendations
- A Few Words About Well Construction, Aquifer Contamination and Methane Leakage

Secretary of Energy Advisory Board

Shale Gas Production Subcommittee 90-Day Report

August 18, 2011

U.S. DEPARTMENT OF ENERGY

Secretary of Energy Advisory Board

Shale Gas Production Subcommittee Second Ninety Day Report

November 18, 2011

U.S. DEPARTMENT OF ENERGY

DOE Shale Gas Subcommittee

- John Deutch – MIT
- Stephen Holditch – Texas A&M
- Fred Krupp – Environmental Defense Fund
- Katie McGinty – Pennsylvania DEP
- Sue Tierney – Massachusetts Energy
- Dan Yergin – Cambridge Energy Research
- Mark Zoback - Stanford

Report Summary

Shale gas can be developed in an environmentally responsible manner

but…..

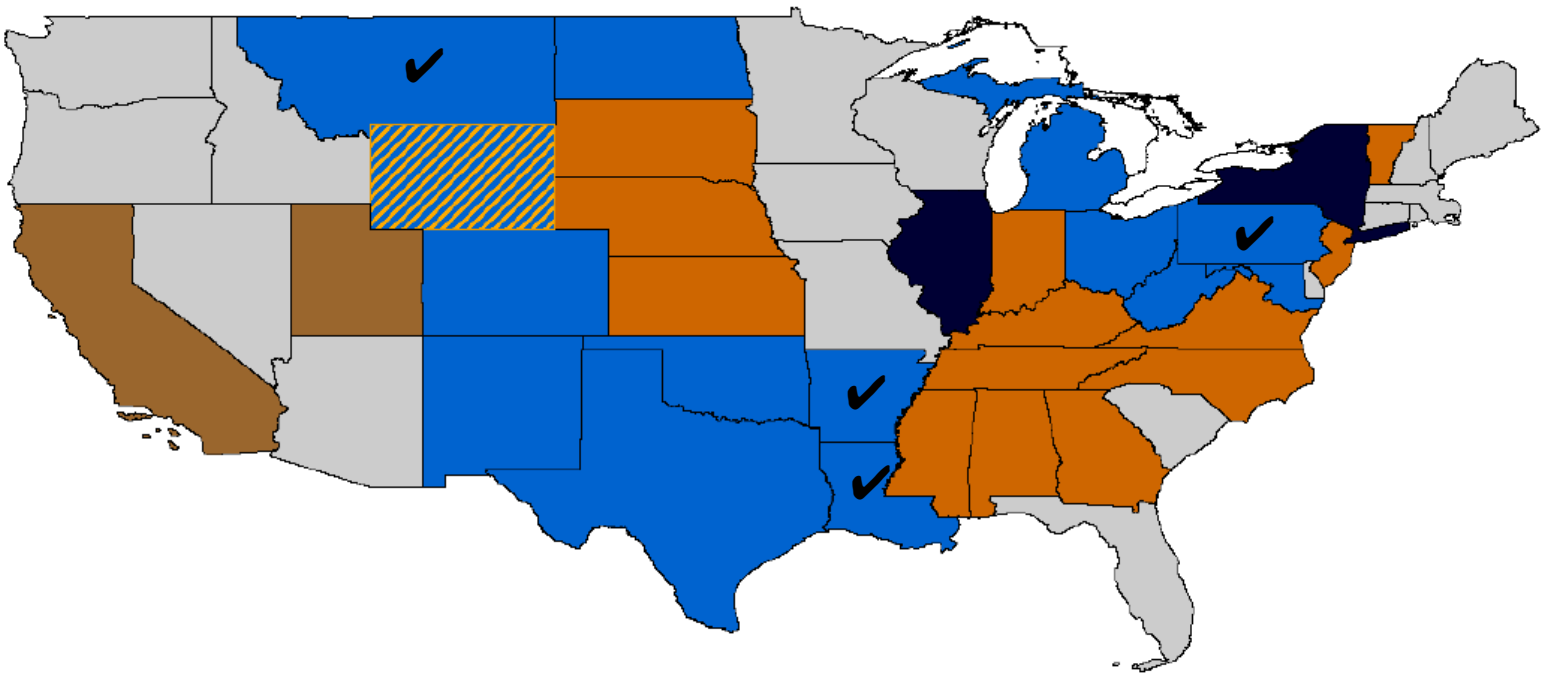
The SEAB Subcommittee Made 20 Recommendations About How to Develop Shale Gas Resources in a More Environmentally Responsible Manner

Four SEAB Recommendations

- Full Disclosure of the Composition of Drilling/Hydraulic Fracturing/Flow Back Fluids
- Full Manifesting of Drilling Fluids/Frac Fluids
- Creation of Regional Centers to Address Issues Such as Finding Optimal Ways to Minimize the Cumulative Impacts of Shale Gas Development
- Sustained Research Support for Continual Improvement of Resource Recovery and Environmental Protection

Full Disclosure of Frac Fluids?

Last updated July 9, 2012



* Require volume disclosure: MD, MI, NM, OH, OK. Concentration disclosure: WY. Volume and concentration: AR, LA, MT, PA

Resources for the Future, Managing the Risks of Shale Gas: Identifying a Pathway Toward Responsible Development A Review of Shale Gas Regulations by State (2012)

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Center for Sustainable Shale Development

- Formerly Institute for Gas Drilling Excellence
- Achieved agreement on proactive action from operators, NGOs
- ~15 high-level performance-based standards for Pennsylvania (& Marcellus)
- Company-level certification*
- Establishment of regional centers

*Well site activities need to be certified
(as well as the companies that carry them out)

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?

Governance Considerations from a Technical Perspective

- Review of Four SEAB Recommendations
- A Few Words About Well Construction, Aquifer Contamination and Methane Leakage

Governance of Well Construction Is a Major Issue

Table 16. Percentage of Experts Who Selected Accidents as a Priority for Additional Action

Accidents	NGO	Industry	Academia	Gov't	All Experts
Cement failure	80.0	58.7	57.1	66.7	63.3
Casing failure	68.6	46.7	61.9	57.1	56.7
Impoundment failure	71.4	33.3	61.9	45.2	50.2
Surface blowout	54.3	34.7	49.2	40.5	43.3
Storage tank spills	42.9	30.7	46.0	28.6	36.7
Truck accidents	37.1	40.0	34.9	28.6	35.8
Pipeline ruptures	42.9	30.7	38.1	33.3	35.3
Surface valve failure	40.0	21.3	27.0	26.2	27.0
Underground well comm.	37.1	14.7	28.6	23.8	24.2
Other spills	22.9	20.0	20.6	23.8	21.4
Underground blowout	31.4	14.7	20.6	23.8	20.9
Hose bursts	22.9	17.3	14.3	16.7	17.2
Other fires or explosions	8.6	13.3	7.9	14.3	11.2
Other not listed here	8.6	5.3	11.1	2.4	7.0
All 14 accidents	40.6	27.2	34.2	30.8	32.2
Average # of accidents selected as high priority	5.69	3.81	4.79	4.31	4.50

Notes: Darkest red is the most often selected for each group, middle red is the second–most often selected, and light red is the third–most selected.

"What the Experts Say About the Environmental Risks of Shale Gas Development." Survey of N=215 NGO, Industry, Regulatory , Academic Experts in shale gas by Resources for the Future. February 2013.

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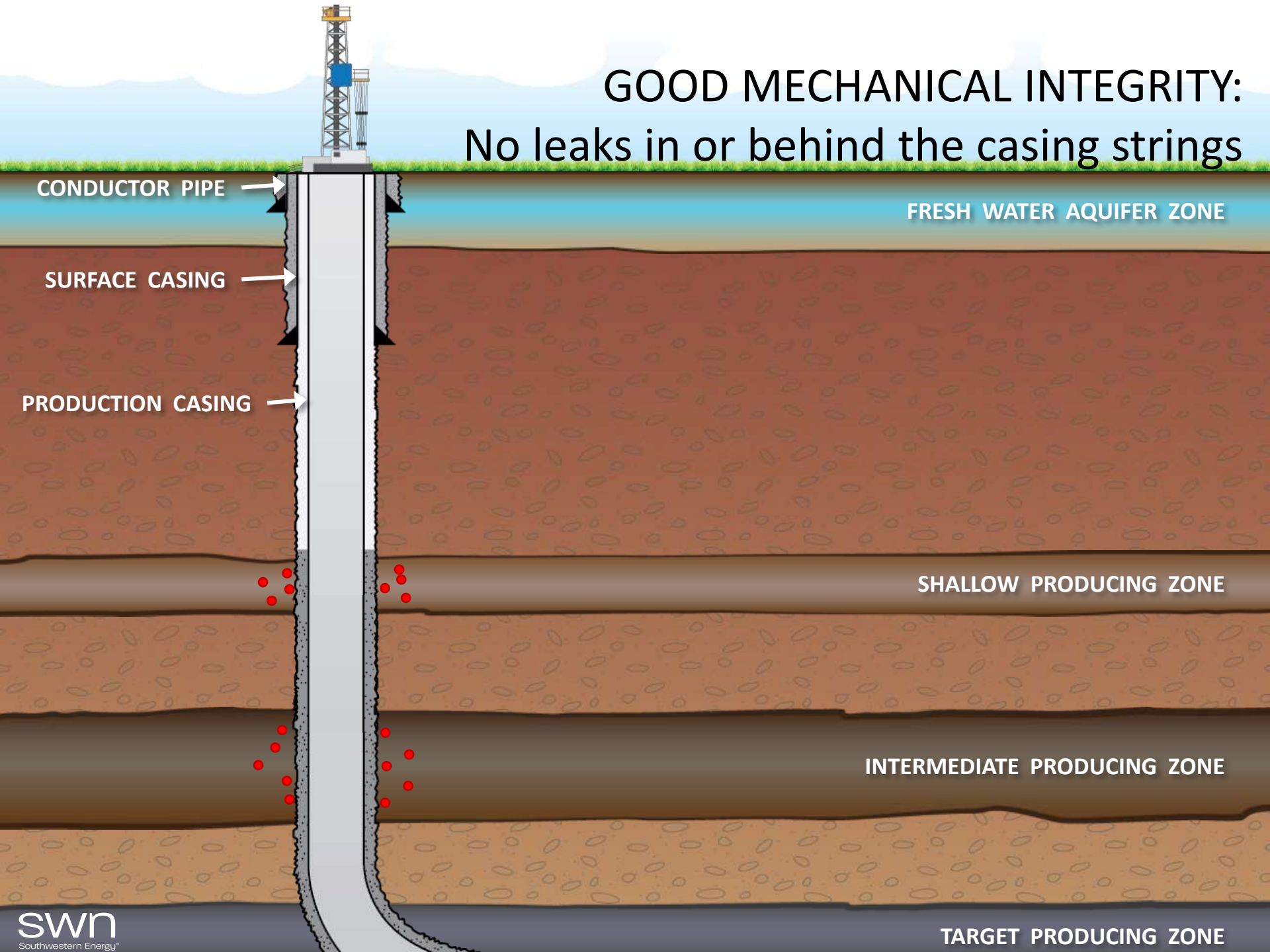
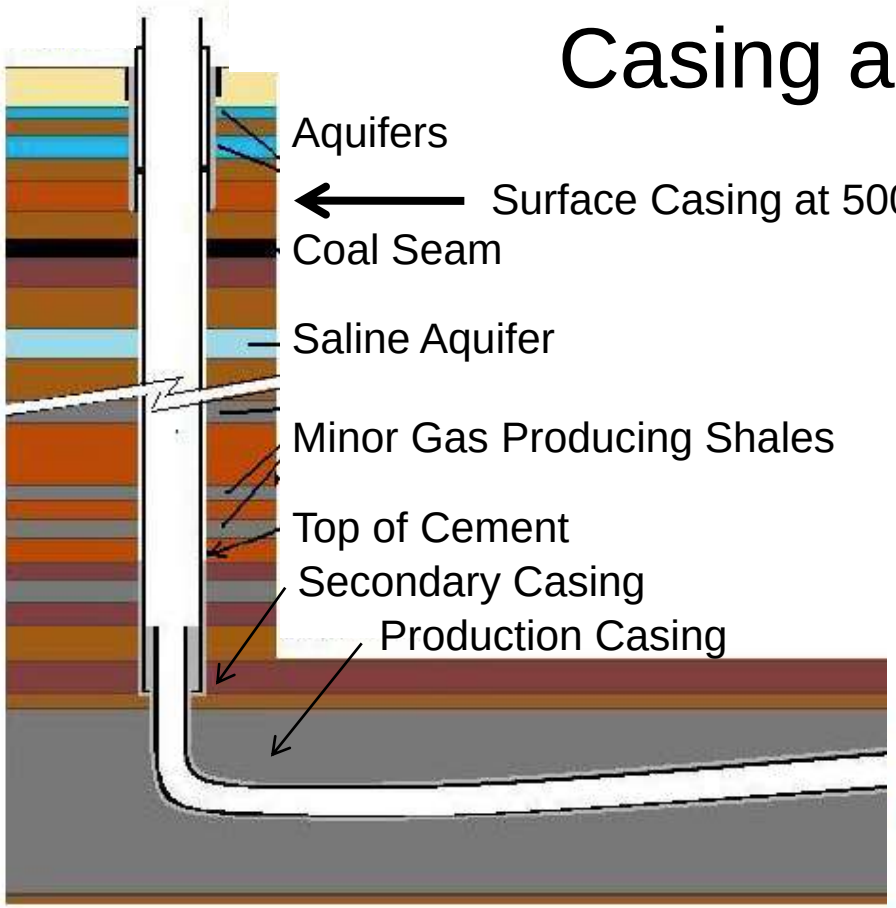
Adopt best practices in well development and construction, especially casing, cementing, and pressure management. Pressure testing of cemented casing and state-of-the-art cement bond logs should be used to confirm formation isolation.

"What the Experts Say About the Environmental Risks of Shale Gas Development." Survey of N=215 NGO, Industry, Regulatory , Academic Experts in shale gas by Resources for the Future. February 2013.

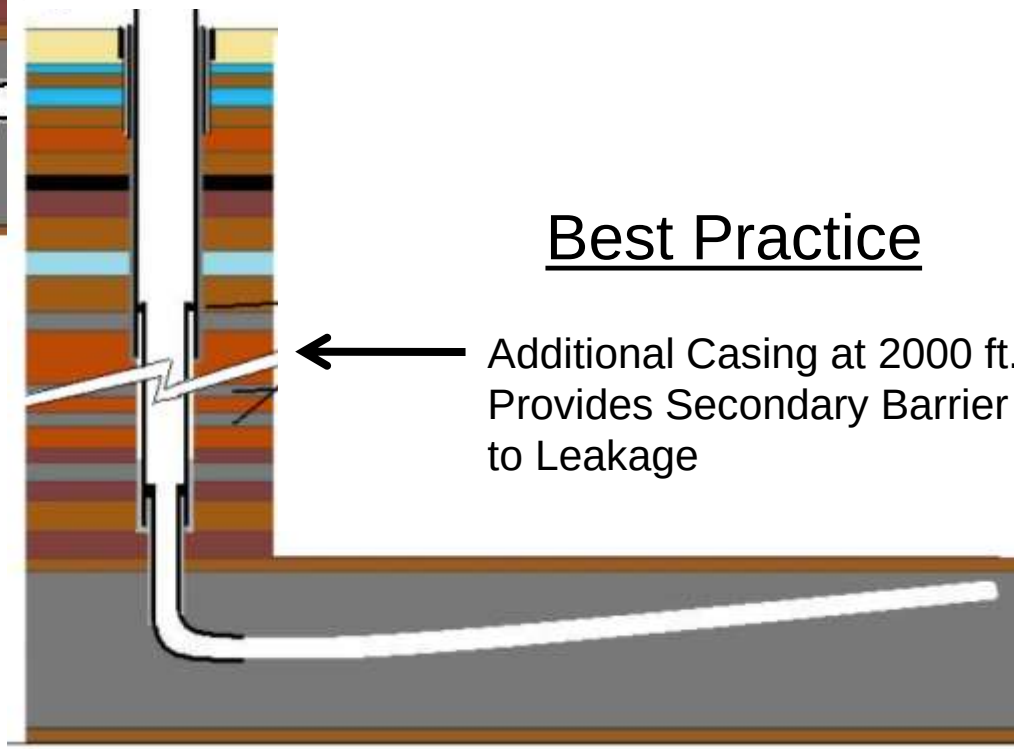

GOOD MECHANICAL INTEGRITY:
No leaks in or behind the casing strings
CONDUCTOR PIPE
SURFACE CASING
PRODUCTION CASING
FRESH WATER AQUIFER ZONE
SHALLOW PRODUCING ZONE
INTERMEDIATE PRODUCING ZONE
TARGET PRODUCING ZONE
swn
Southwestern Energy

Casing and Cementing Critical



API Recommended Practice

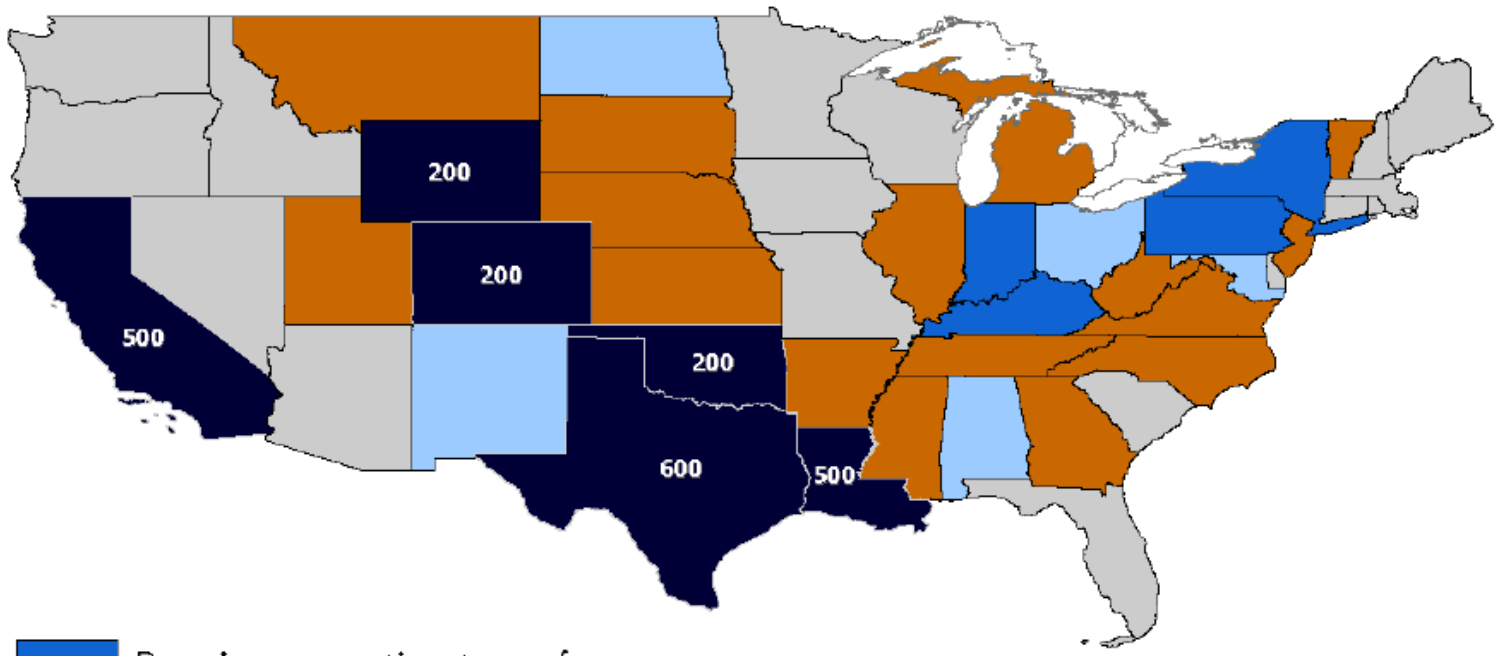
Best Practice



George King, SPE 152596 (2012)

Cementing of Intermediate Casing?

Last updated July 9, 2012



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Range Resources
Washington County, Pennsylvania

JISEA Joint Institute for Strategic Energy Analysis

Natural Gas and the Transformation of the U.S. Energy Sector: Electricity

Jeffrey Logan, Garvin Heath, Jordan Macknick

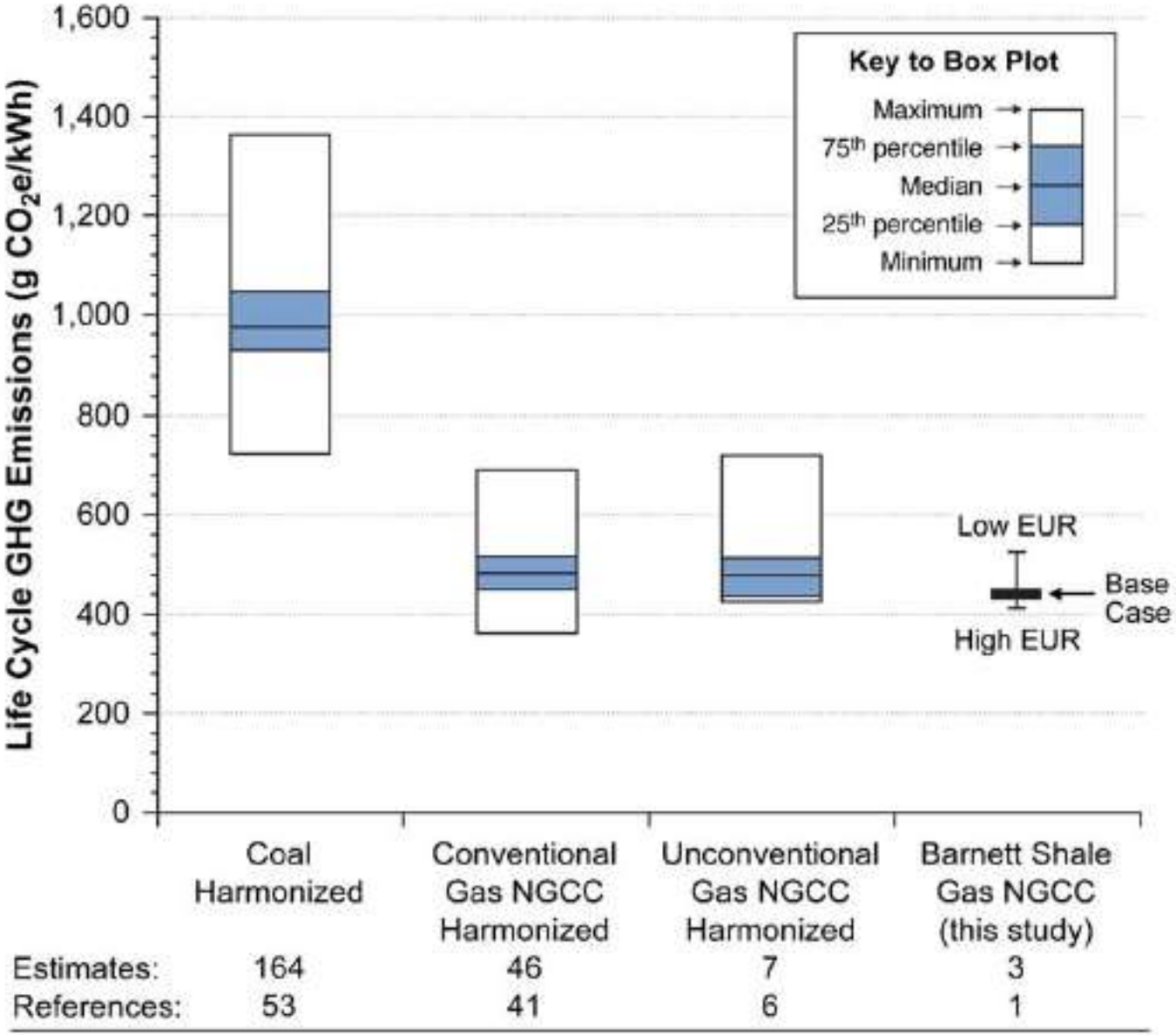
National Renewable Energy Laboratory

Elizabeth Paranhos, William Boyd

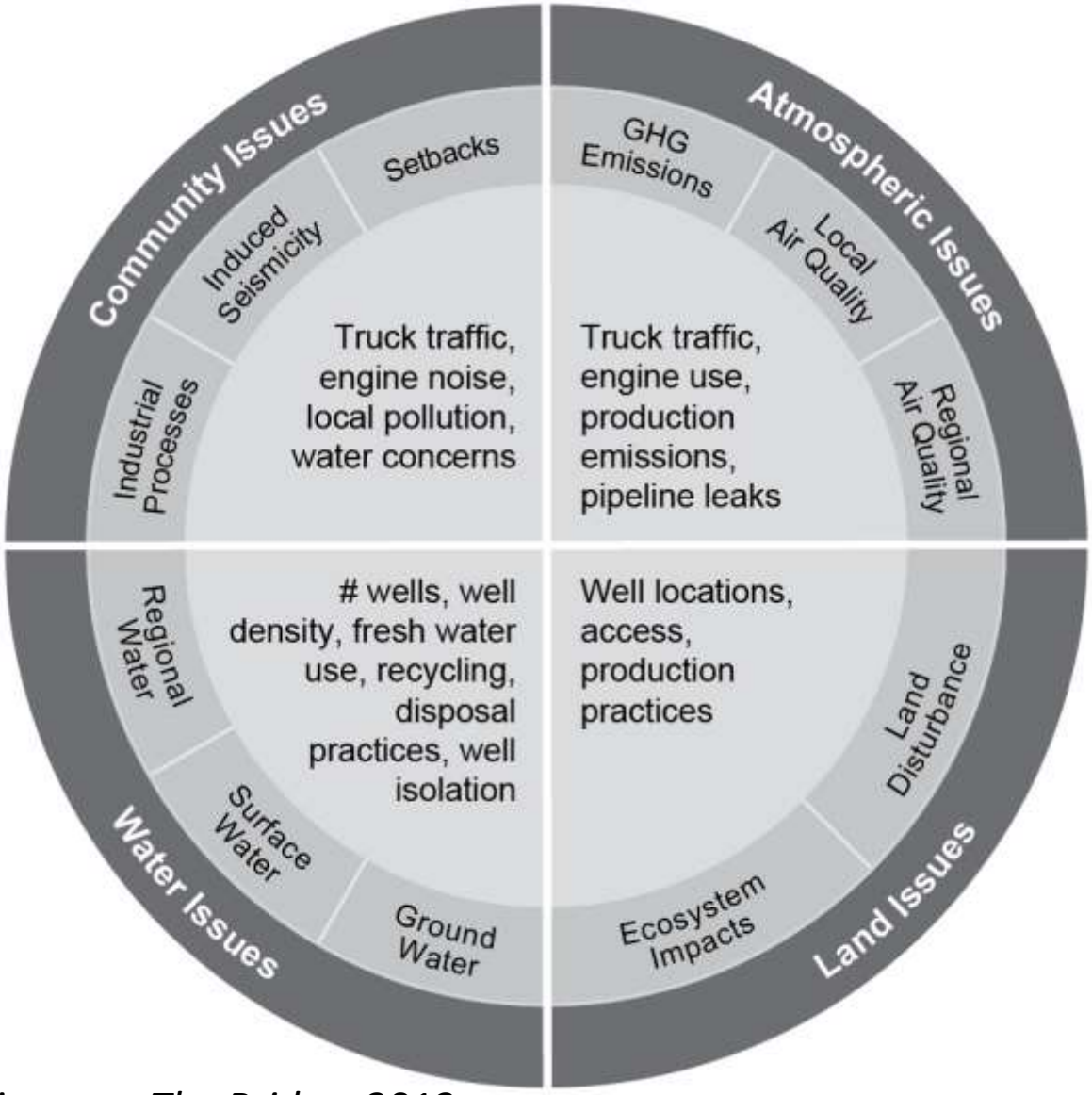
University of Colorado Law School

Ken Carlson

Colorado State University


Life Cycle GHG Emissions (g CO_2e/kWh)
1,600
1,400
1,200
1,000
800
600
400
200
0
Key to Box Plot
Maximum
75th percentile
Median
25th percentile
Minimum
Low EUR
Base Case
High EUR
Coal Harmonized
Conventional Gas NGCC Harmonized
Unconventional Gas NGCC Harmonized
Barnett Shale Gas NGCC (this study)
Estimates: 164 46 7 3
References: 53 41 6 1

Governance Considerations from a Technical Perspective Are Multi-faceted



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