The scientific perspective on shale gas environmental issues: More facts, less speculation!

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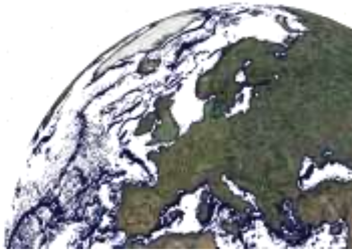
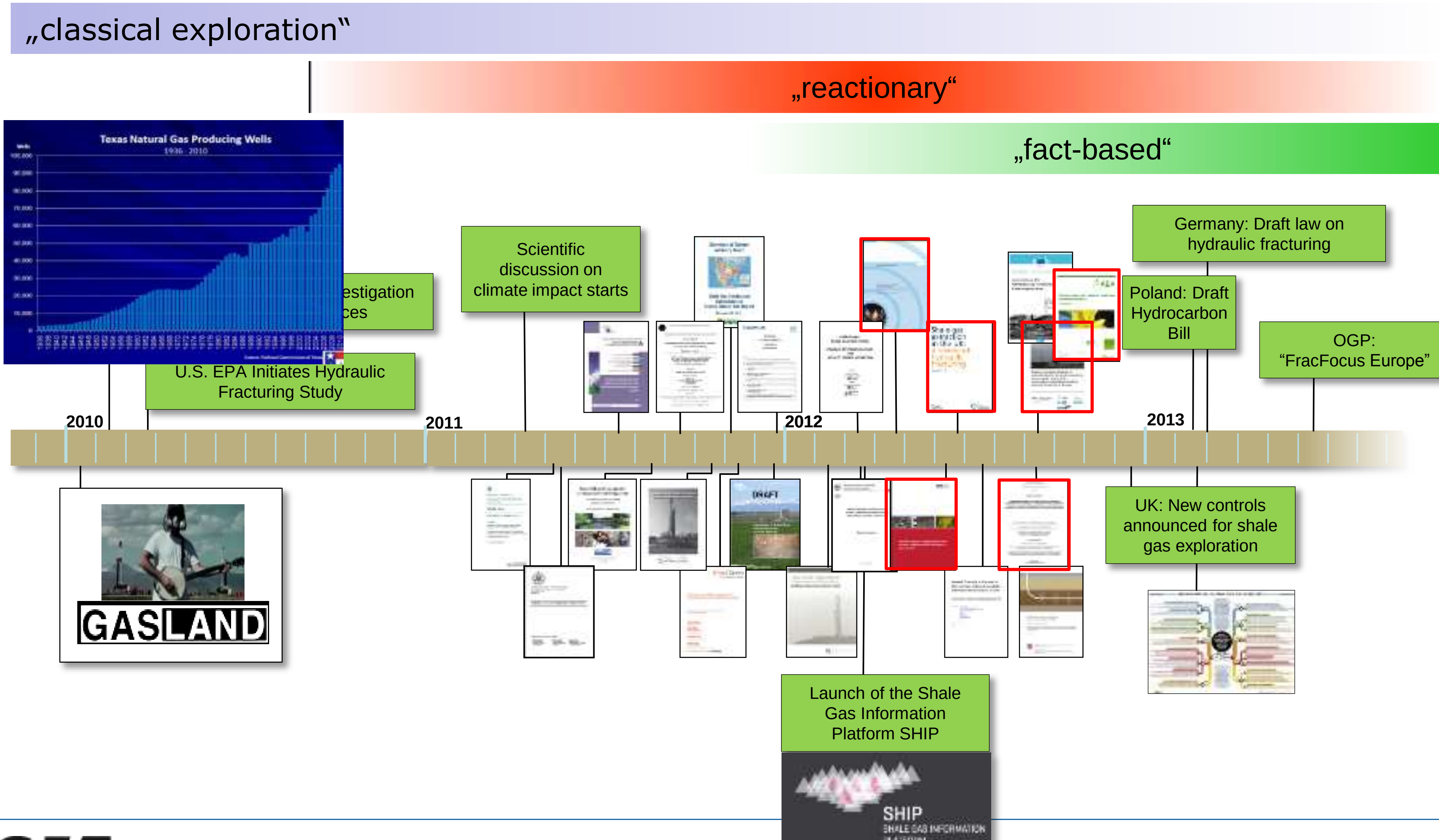
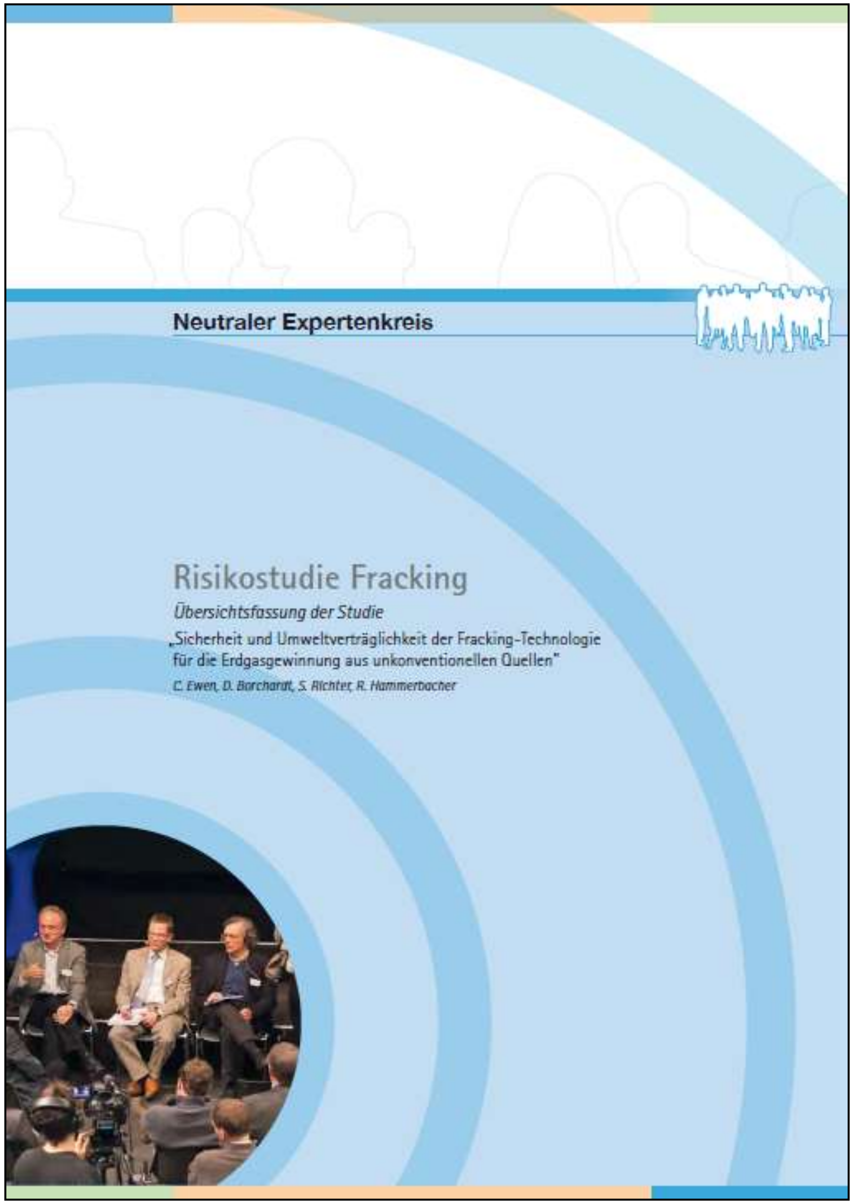


The long and winding road

To deploying environmentally compatible hydraulic fracturing in Europe





Information and Dialogue Process ExxonMobil on Hydraulic Fracturing

- Compared to conventional gas production, hydraulic fracturing in unconventional reservoirs bears a new dimension of risks.
- There is no factual reason for a ban of the technology.

German Federal Institute for Geosciences and Natural Resources

- From a geoscientific point of view, environmentally sustainable application of the technology is possible.
- Hydraulic fracturing is compatible with the protection of freshwater reservoirs.

Shale gas extraction in the UK: a review of hydraulic fracturing

June 2012

THE ROYAL SOCIETY

ROYAL ACADEMY OF ENGINEERING

Royal Society/Royal Academy of Engineering

- The health, safety and environmental risks can be managed effectively in the UK.
- Fracture propagation is an unlikely cause of contamination.
- Robust monitoring is vital.
- Seismic risks are low.
- Regulation must be fit for purpose.

Bundesministerium
für Umwelt, Naturschutz
und Reaktorsicherheit

Umweltauswirkungen von Fracking bei der Aufsuchung und Gewinnung von Erdgas aus unkonventionellen Lagerstätten – Risikobewertung, Handlungsempfehlungen und Evaluierung bestehender rechtlicher Regelungen und Verwaltungsstrukturen

von

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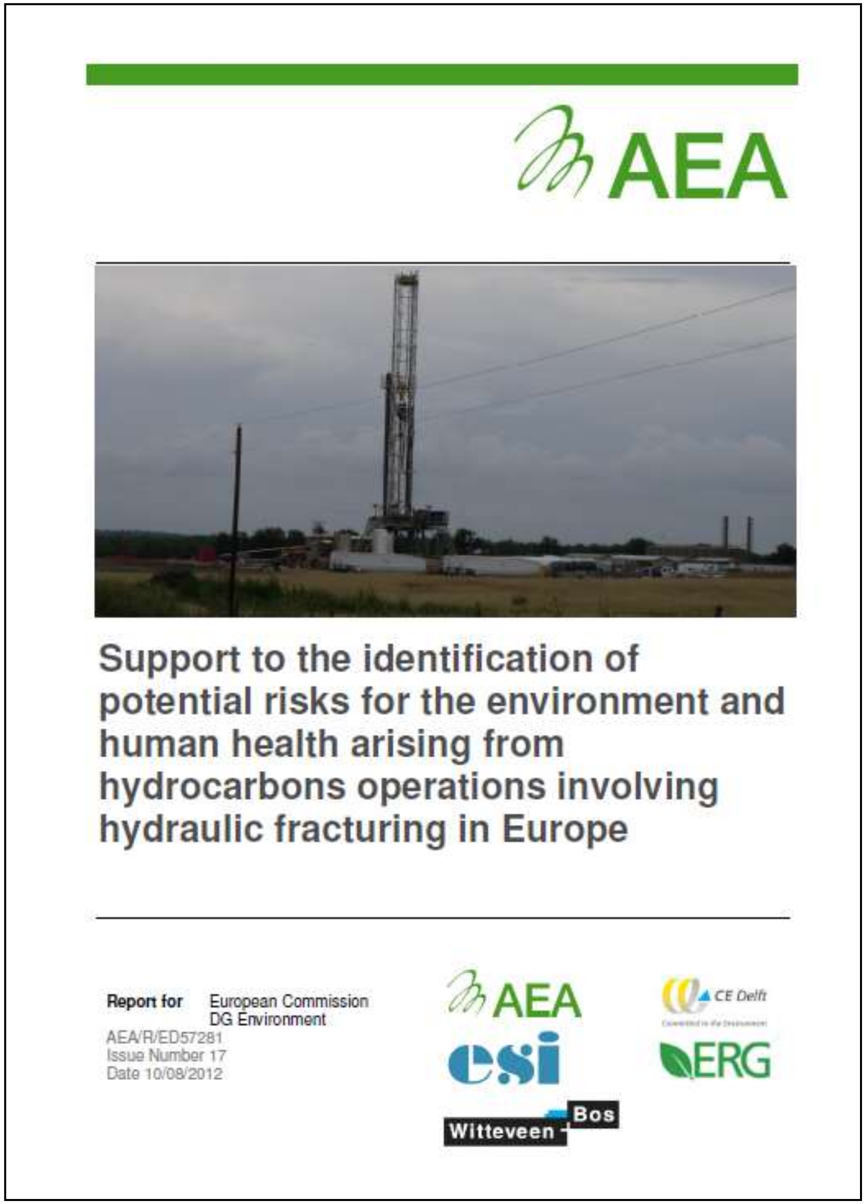
IM AUFTRAG
DES UMWELTBUNDESAMTES

August 2012

German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety

- No ban on hydraulic fracturing.
- No drilling and hydraulic fracturing in regions with unfavorable geological and hydrogeological conditions.
- Disclosure of constituents in fracturing fluids.
- Development of monitoring programs for groundwater and surface monitoring.
- Mandatory Environmental Impact Assessment.


AEA

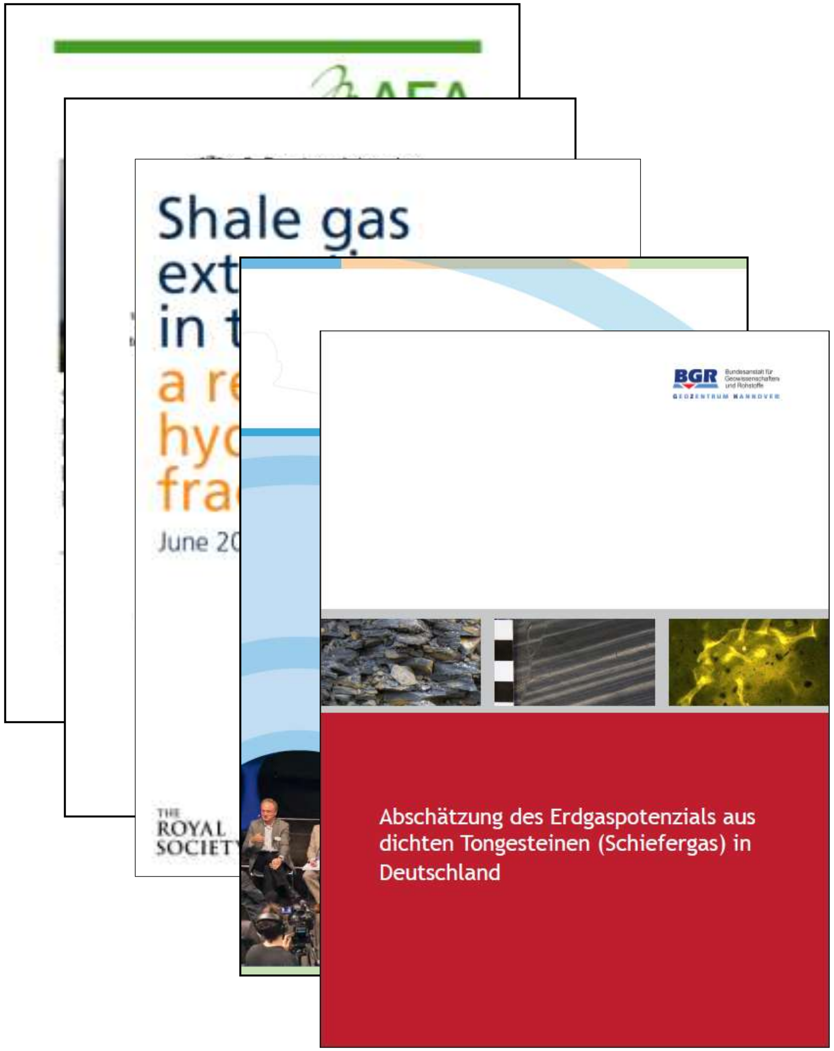
Support to the identification of potential risks for the environment and human health arising from hydrocarbons operations involving hydraulic fracturing in Europe

Report for European Commission DG Environment
AEA/R/ED57281
Issue Number 17
Date 10/08/2012

AEA
CE Delft
esi
ERG
Witteveen + Bos

European Commission

- Cumulative projects have high risk of surface and groundwater contamination, water resource depletion, air and noise emissions, land take, disturbance to biodiversity and traffic-related impact.
- Extensive review of the practices, legislation, and standards that can be used to manage hydraulic fracturing risks.



- No ban on hydraulic fracturing
- Pre-drilling knowledge of regional and site-specific geology essential
- Monitoring programs for groundwater and surface monitoring
- Legislation must be fit for purpose

Concerns

- Groundwater contamination
- Induced Seismicity
- Greenhouse gas emissions

Concerns

- Groundwater contamination
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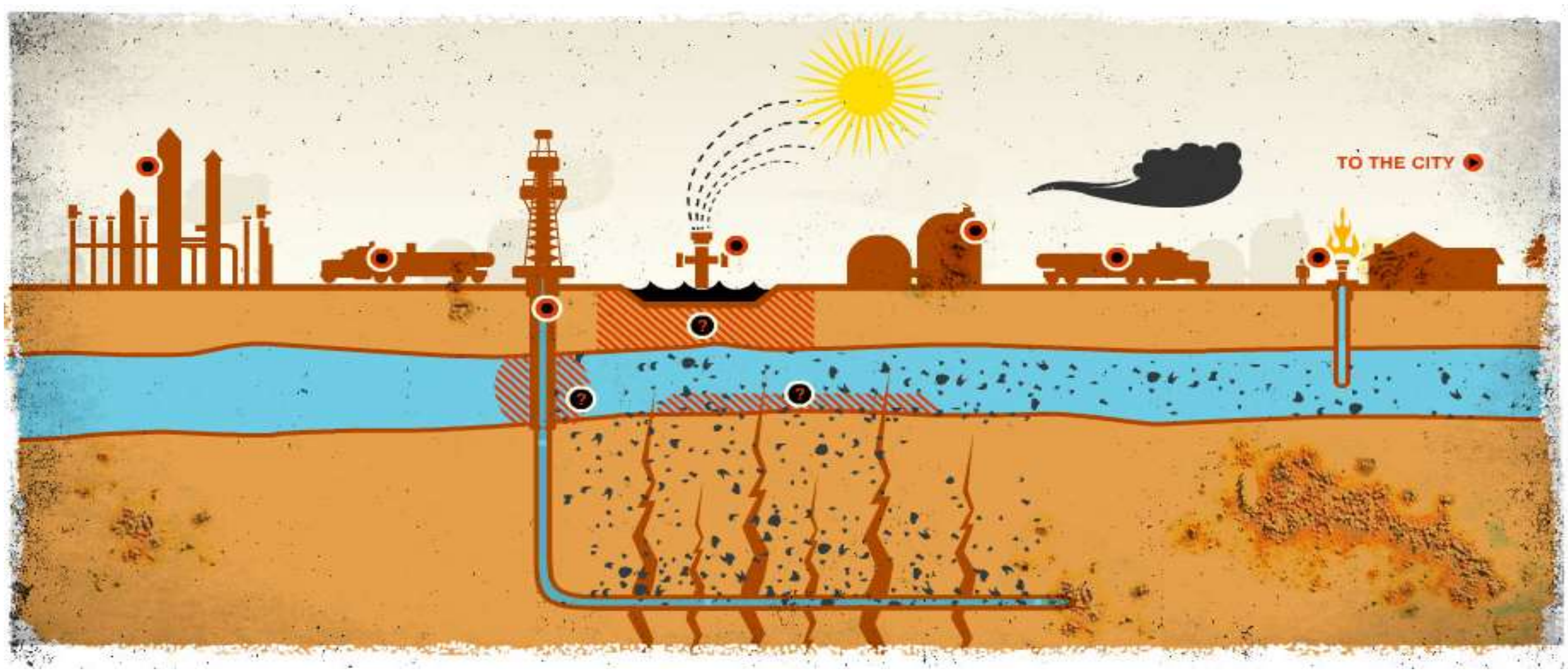
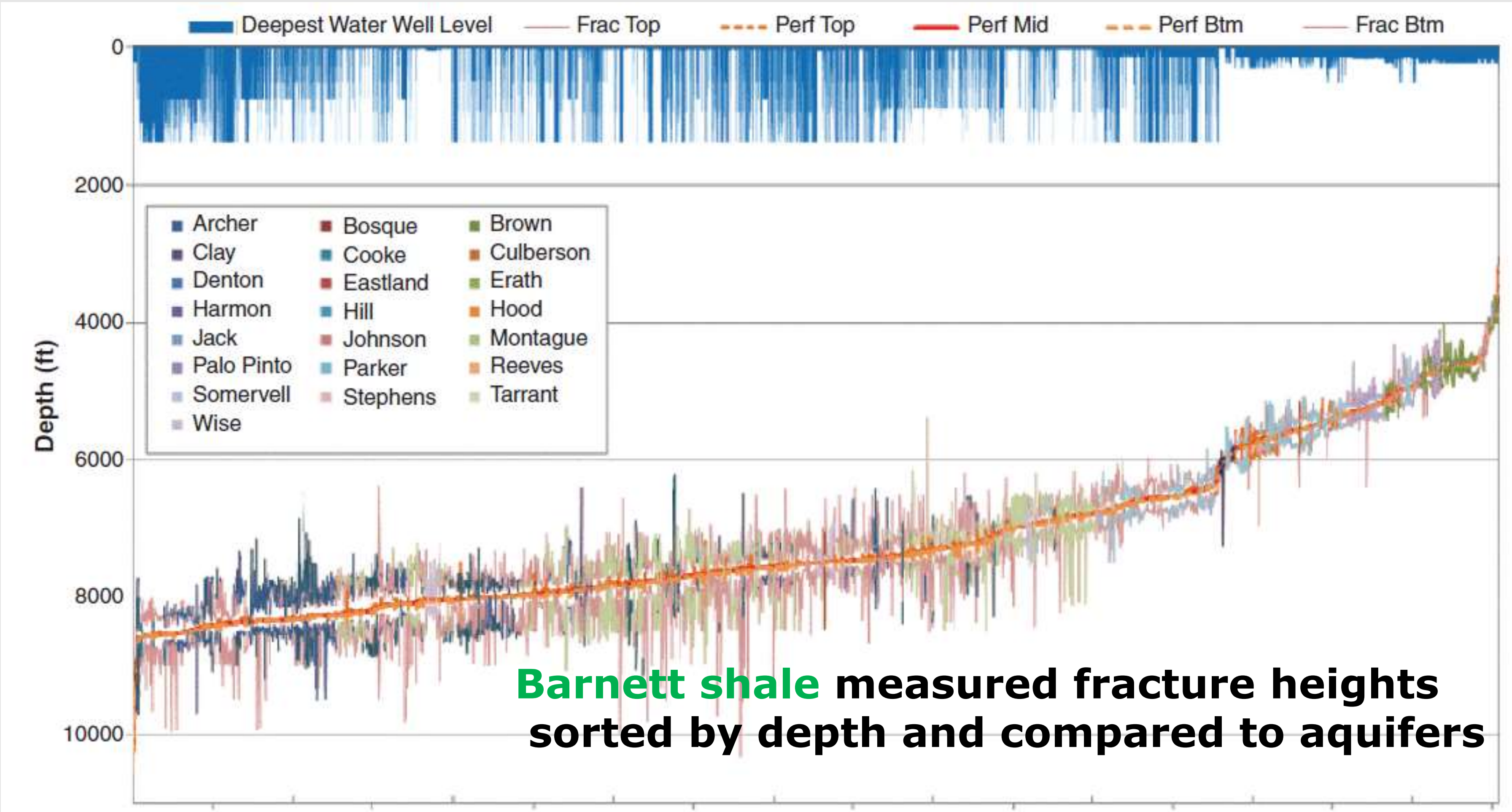
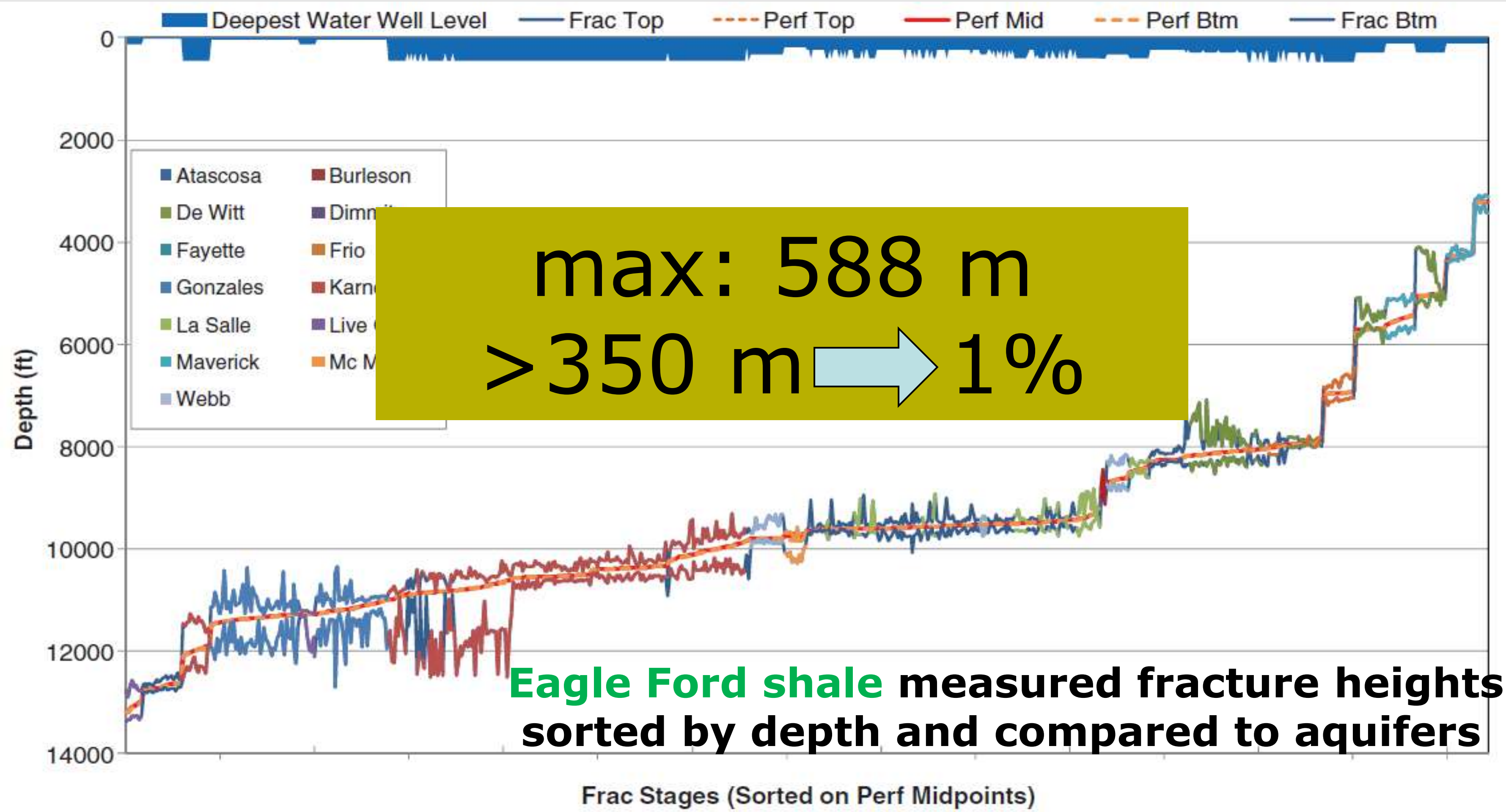
wrong and misleading



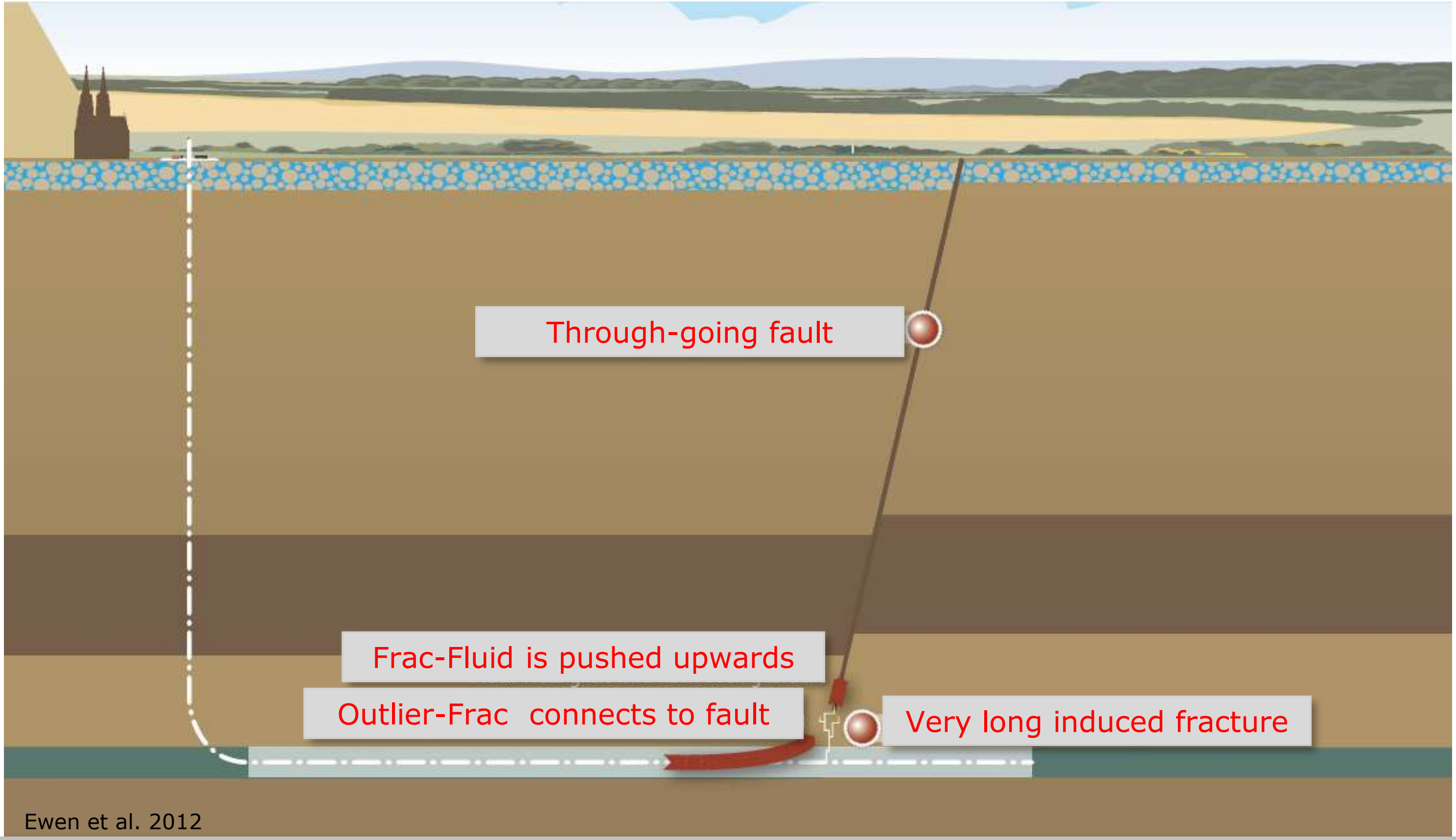
Barnett shale measured fracture heights sorted by depth and compared to aquifers



Fisher and Warpinski 2011



Fisher and Warpinski 2011



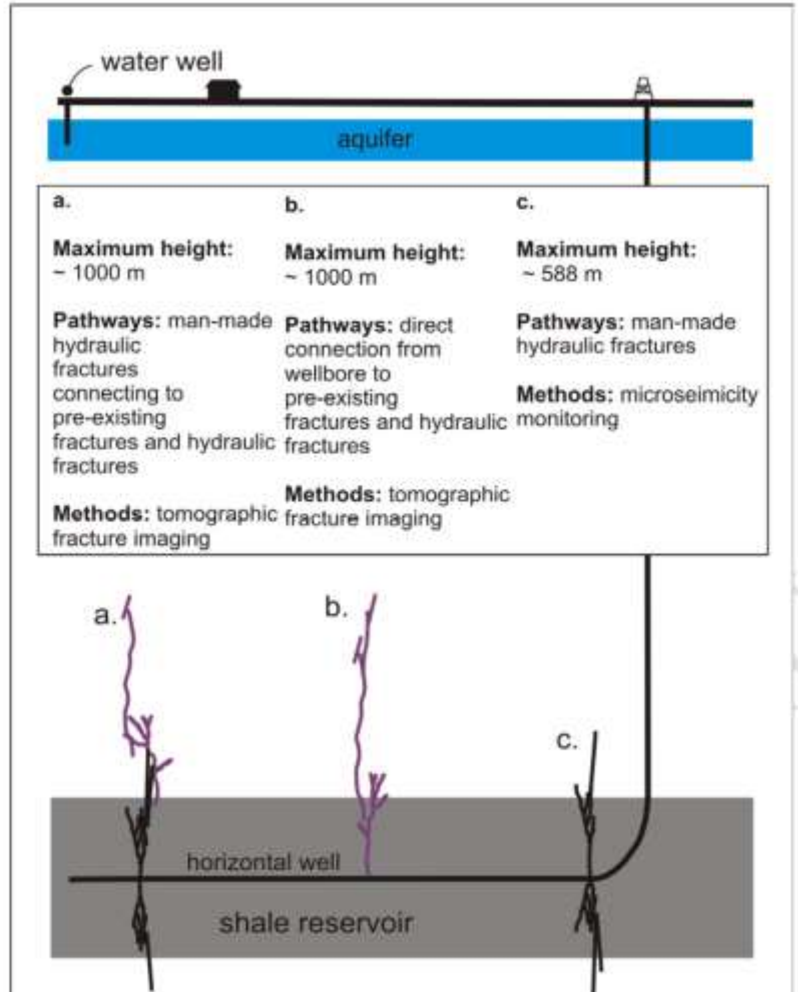
Modeling shows that even with conservative presumptions the fluids pumped in the underground could rise only about 50 m. They may rise only as long as the fracturing pressure is maintained. That means: no contaminants will enter the freshwater resources via this route.

Fault reactivation

Seismic activation of pre-existing faults was detected up to nearly 1000 m.

(Lacazette und Geiser 2013)

- Pre-drilling knowledge of regional and site-specific geology essential
- Identify directions of local stresses and locations of pre-existing faults



Davies 2013a

Concerns

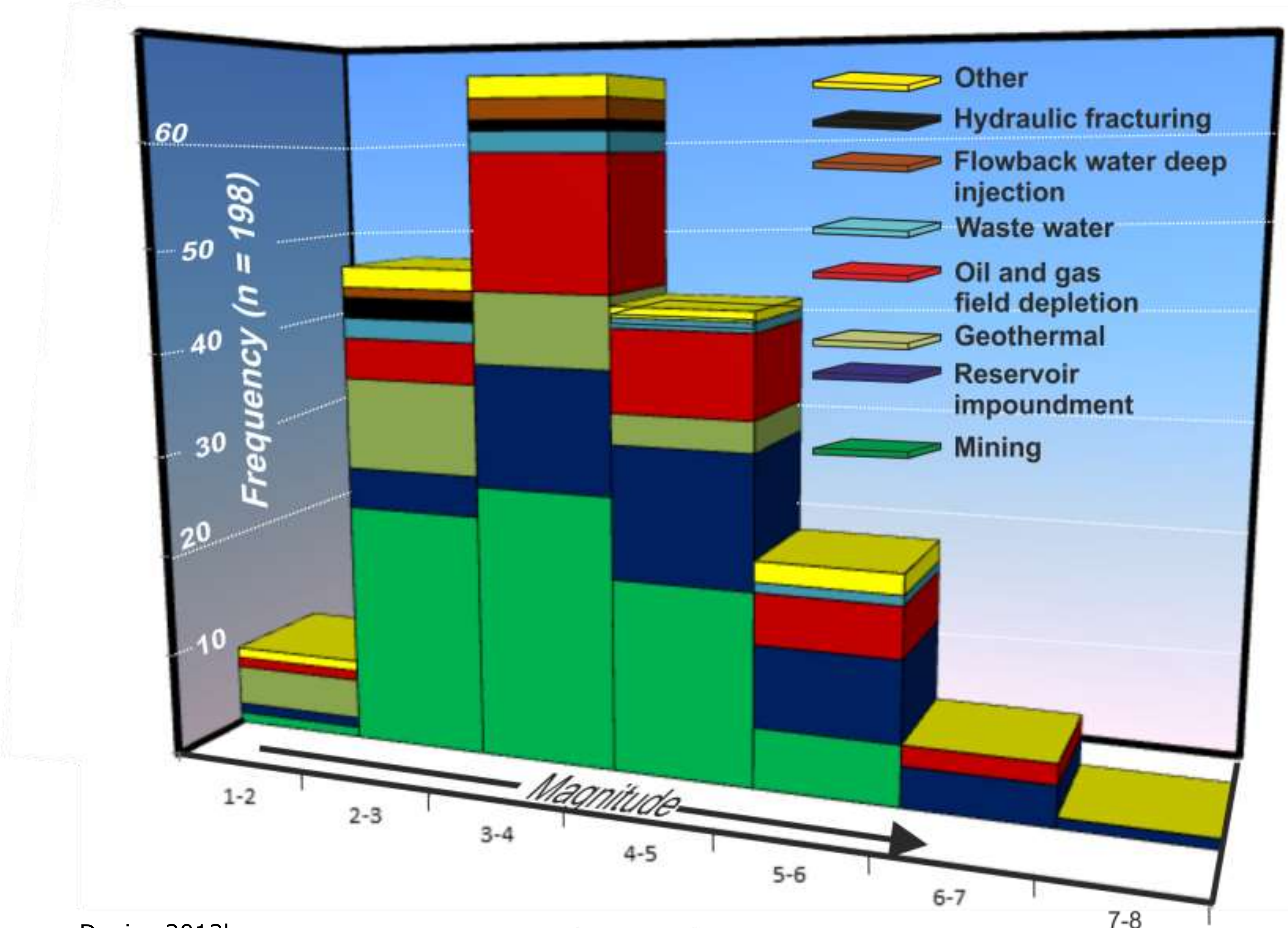
- Groundwater contamination
- Induced Seismicity
- Greenhouse gas emissions

Review Article
Marine and Petroleum Geology (2013)
Davies, R., Foulger, G., Bindley, A., Styles, P.

Induced Seismicity and Hydraulic Fracturing for the Recovery of Hydrocarbons

Compilation of published examples of induced earthquakes since 1929.

"Hydraulic fracturing is not an important mechanism for causing felt earthquakes."



Davies 2013b

Concerns

- Groundwater contamination
- Induced Seismicity
- Greenhouse gas emissions


AEA

Climate impact of potential shale gas production in the EU

Final Report

ERG

milieu

Report for European Commission DG CLIMA

AEA/R/ED57412

Date 30/07/2012

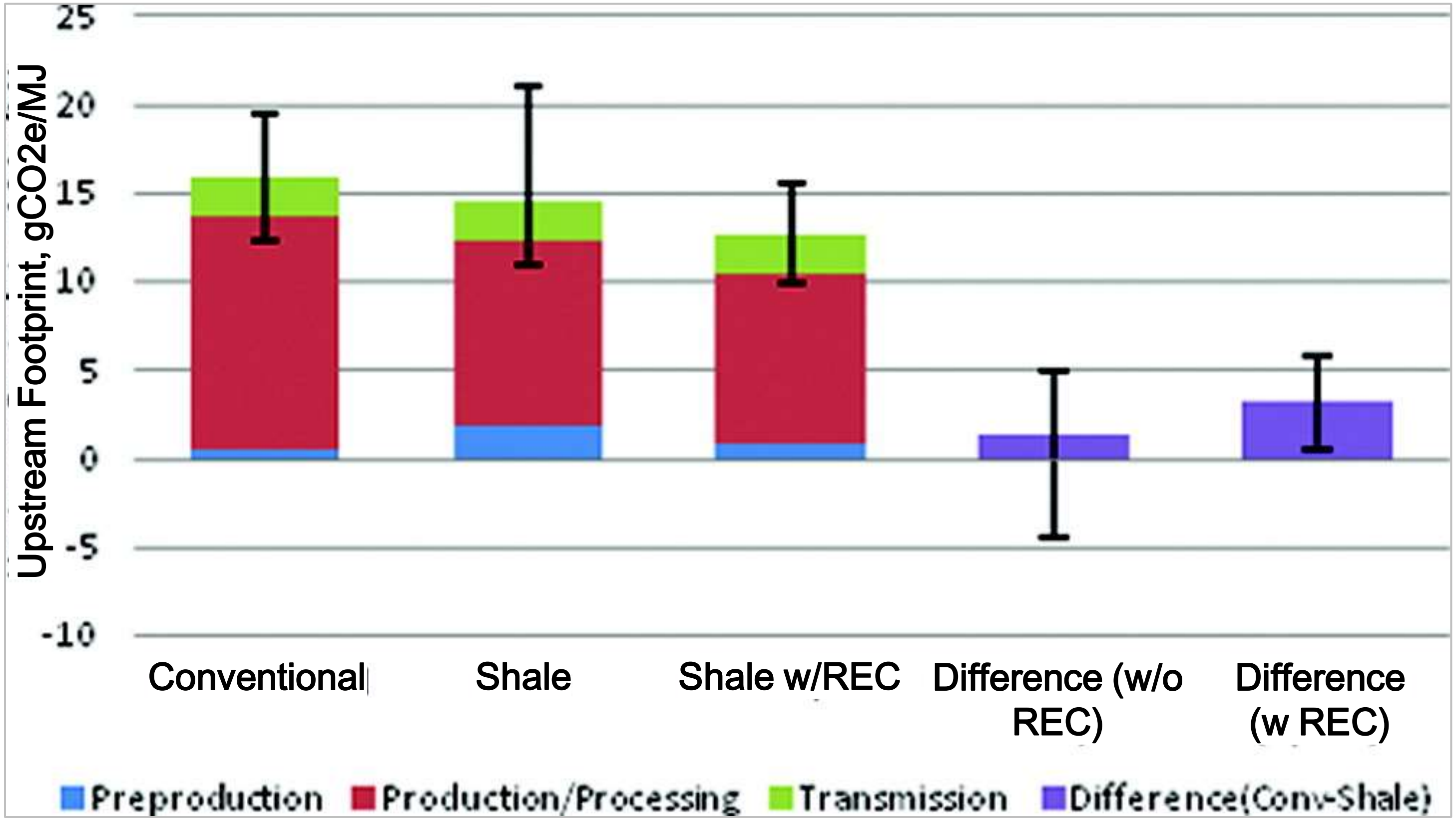
Issue 2

CE Delft

European Commission

- If emissions from well completion are mitigated, through flaring or capture, and utilised then this difference is reduced to 1% to 5%.
- This finding is broadly in line with those of other U.S. studies …

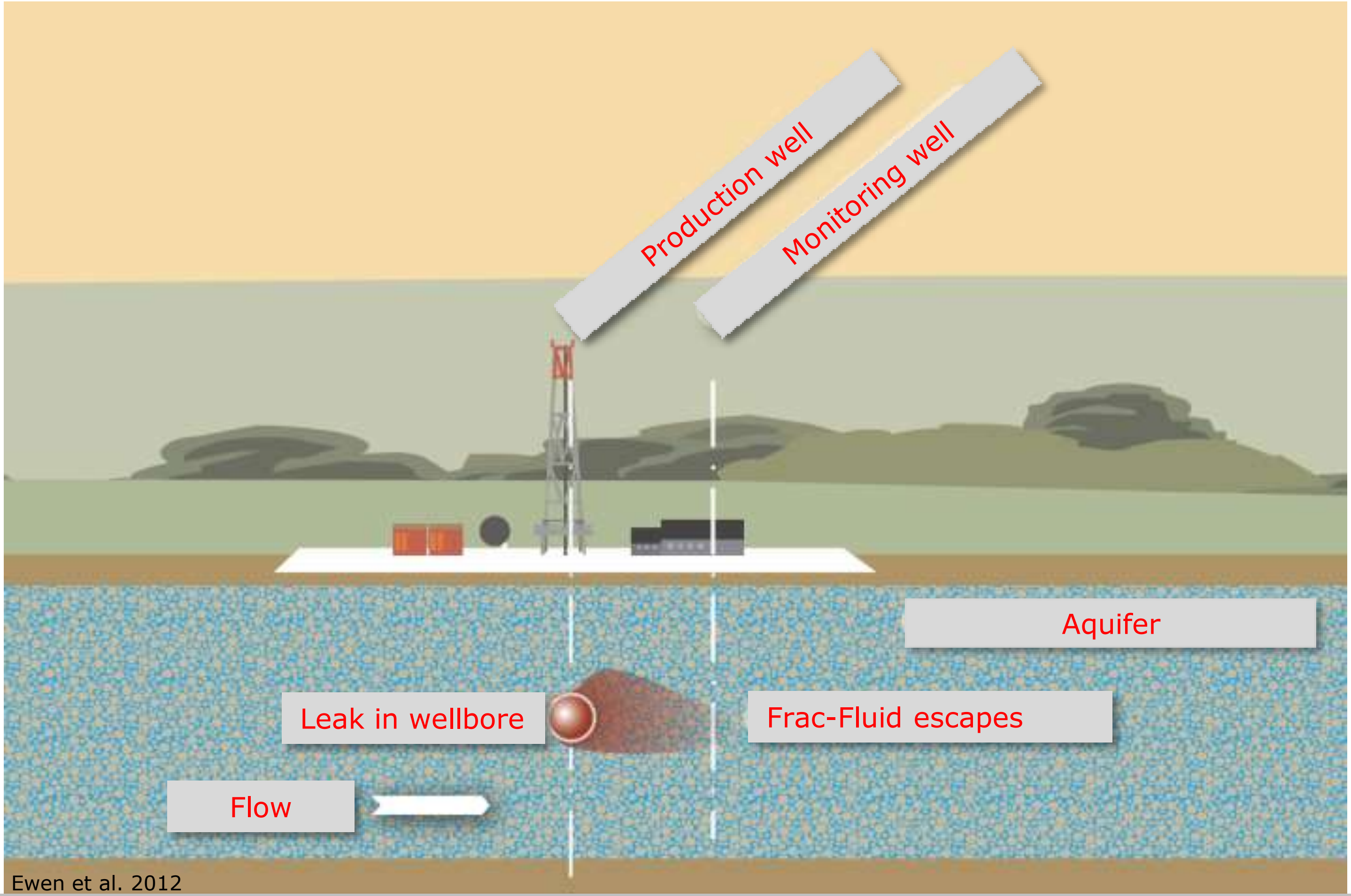
Life Cycle Carbon Footprint of Shale Gas: Review of Evidence and Implications



Weber and Clavin 2012

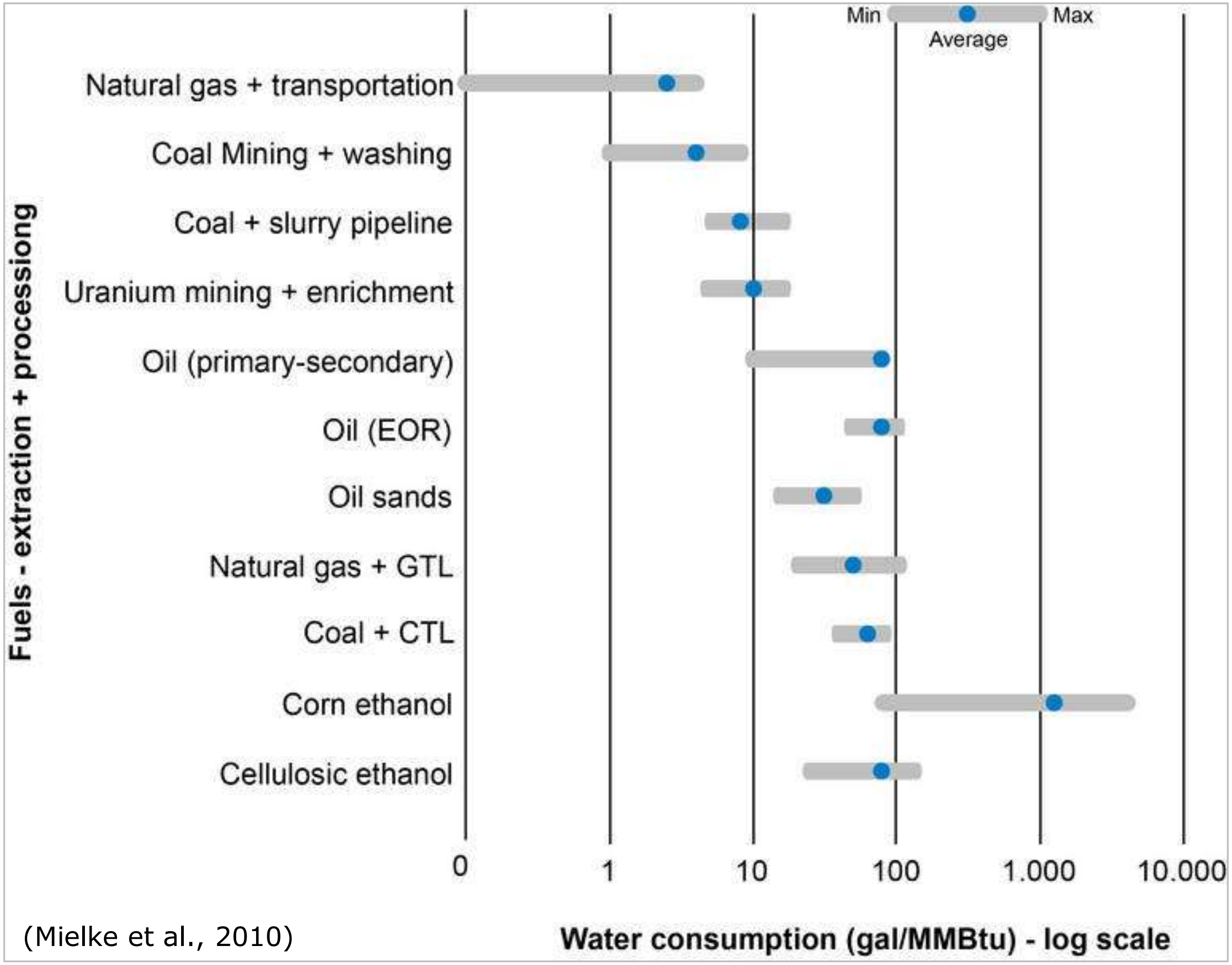
- A large scientific knowledge base already exists
- Some topics need further research
- Knowledge base, incl. uncertainties, should be used in discussion and decision making
- Research organisations have an active and defining role to play in the balanced and fact-based discussion on shale gas environmental issues

Thank you for your attention

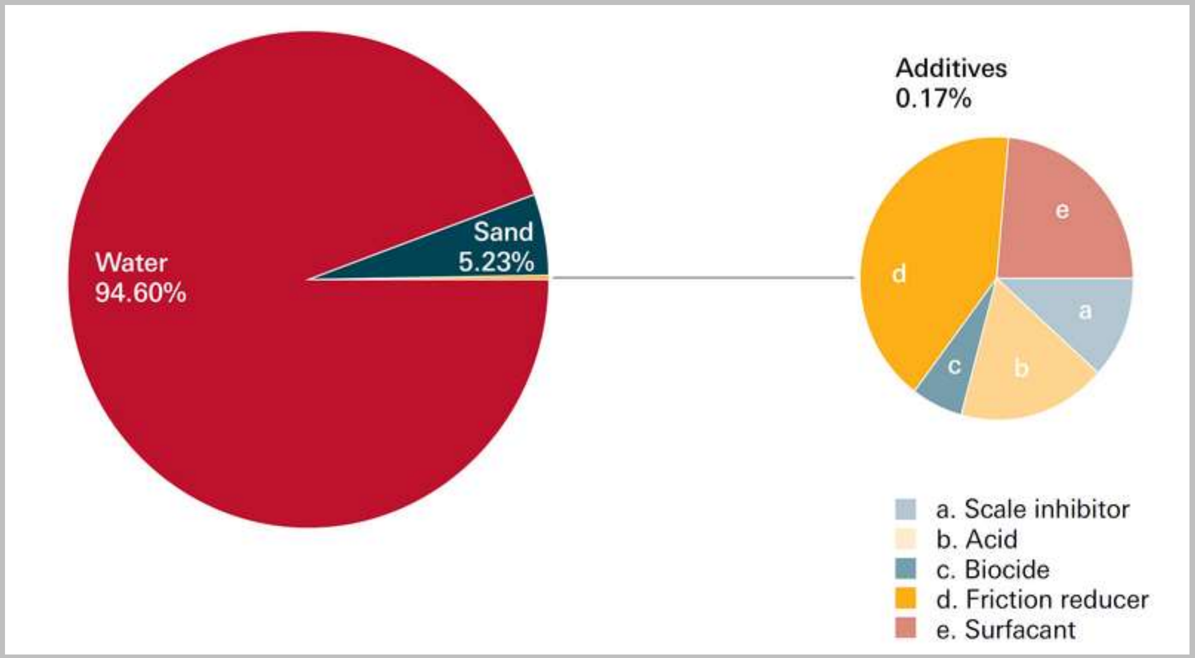


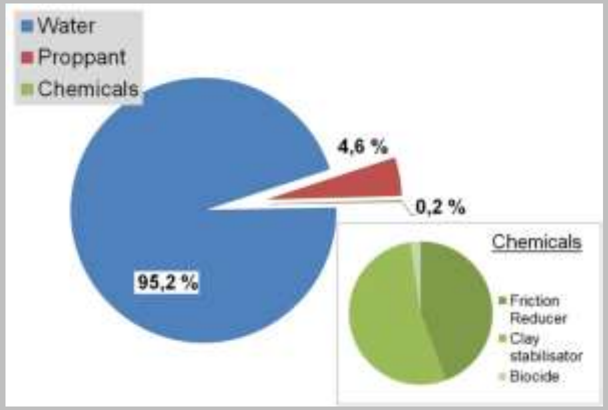
Leaky cement and casing may be avoided by state-of-the-art technology.

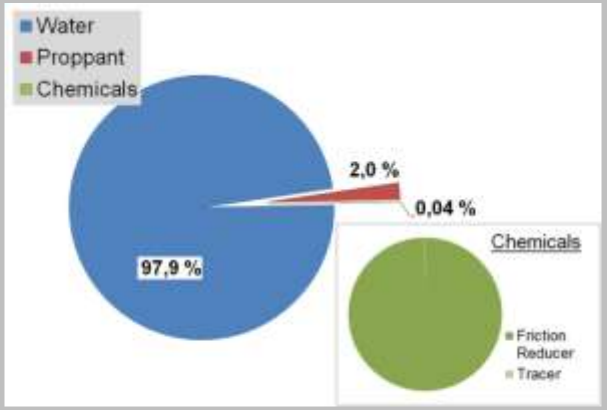
We assume that one small or larger leak will occur with every 300 shale gas wells and about 4000 fracs.



(Mielke et al., 2010)


Additives
0.17%
Sand
5.23%
Water
94.60%
e
d
a
c
b
a. Scale inhibitor
b. Acid
c. Biocide
d. Friction reducer
e. Surfacant


Water
Proppant
Chemicals
4,6 %
0,2 %
95,2 %
Chemicals
Friction Reducer
Clay stabilisator
Biocide


Water
Proppant
Chemicals
2,0 %
0,04 %
97,9 %
Chemicals
Friction Reducer
Tracer

Additive Class	Purpose	Examples
Biocide	Avoiding growth of bacteria and other fauna	Terpenes, isothiazolinones (e.g. 1,2-benzisothiazol-3-(2H)-one or 2-methyl-4-isothiazolin-3-one)
Buffer	pH control	Anorganic acids and bases (e.g. hydrofluoric acid, ammonium bisulfite)
Breaker	Reducing viscosity, enhanced fluid retrieval	Sulfates, peroxides (e.g. Ammonium persulfate, calcium peroxide)
Corrosion Inhibitor	Protect casing and equipment	Acids, alcohols, sulfites, (e.g. 2-butoxyethanol, amine bisulfite)
Crosslinker	Support gel formation, increase viscosity for proper downhole transportation of sand.	Borates, transition metals in combination with complexing agents (e.g. zirconiumoxide, -sulfate)
Friction Reducer	Creates laminar instead of turbulent flow	Polyacrylamide, petroleum distillates, e.g. aromatic hydrocarbons (benzene, toluene)
Gelling Agent	Support gel formation, increase viscosity for proper downhole transportation of sand, ideal proppant carriage	Guar gum, hydroxyethylcellulose, polymers (e.g. acrylamidcopolymers, vinylsulfonates)
Scale Inhibitor	Avoid precipitates from mineralic scalings that may build up at the inner wall of the casing or in the wellhead	Acids, phosphonates, (e.g. dodecylbenzene, sulfonic acid, calcium phosphonate)
Surfactant	Emulsification and salinity tolerance	Amines, glycol ethers, nonylphenol ethoxylates