Polish expertise in shale gas exploration –
with special emphasis on environmental impact

Paweł Poprawa
global shale gas potential (after: PETRENEEL)
shale gas impact on US economy

• recently shale gas stands for ~ 25 % US gas production
• cumulative shale gas investments in US ~80 bln USD/year
• no import of gas to US – export of LNG gas; US become the biggest gas producer in the World
• decrease of gas price in USA in 2008-2009 – bigger nominal profit than all federal support to US economy
• investment of 1 mIn USD/year creates 14 jobs; direct – 4, indirect – 4,5, induced – 5,5)
• investment of Encana in British Columbia (W Canada) 80.000 jobs (50-60 % spending remains in local economy)
potential shale gas basins in Europe
Poland – a rush shale gas market

shale gas potential

early 2007
Poland – a rush shale gas market
Poland – a rush shale gas market

- >70 concession blocks (up to 1.200 km\(^2\) each) for shale gas exploration granted during last 3-4 years
- approx. 60,000 km\(^2\) covered with exploration concessions
- some 15 companies currently active on the market, including: ExxonMobil, ConocoPhillips, Chevron, Marathon, Talisman, ENI, Total, Encana, Nexen & others
environmental impact
• fracturing applied since 1949
• up to 1 million frac jobs were done so far – large experience
• 1.000-5.000 m³ of water per one stage; some 20 % at average flows back to surface
• contains water, sand (proppant), chemical additives, rock debris, natural formation brines
• requires utilization / permits and control
unverified non-expert concepts with impact on decision makers
shale gas expertise in Poland

• cooperation/training with US and Canadian public administration & environment protection agencies (EPA, USGS, BCO&GC, etc)
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• preliminary environment impact assessment in 2010
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• preliminary environment impact assessment in 2010

• current research project: monitoring of drillings and frac jobs, including aquifers, air, soil, noise, tremors, frac fluid and flow back water analysis
Poland – an European natural lab for environment impact analysis of gas and oil production from shale and tight reservoirs

- shale gas: 10 wells drilled (5 completed)
- tight gas: 6 wells drilled (3 completed)
- coming 2-3 years up to 200 wells drilled and completed
Poland – an European natural lab for environment impact analysis of gas and oil production from shale and tight reservoirs

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• tight gas: 6 wells drilled (3 completed)

• coming 2-3 years up to 200 wells drilled and completed
Methane in water taps?
unverified non-expert concepts with impact on decision makers
hazard of aquifer contamination during drilling and production?
pollution of aquifers by frac fluid?
hazard of aquifer contamination during fracturing?

- Precambrian crystalline basement
- Cambrian tight sandstone & mudstone
- Ordovician carbonate & clastic sediments
- Upper Silurian shale & mudstone – regional seal
- Zechstein evaporites
- Triassic sandstone & mudstone & carbonates
- Jurassic sandstone, marl & limestone
- Cretaceous marl
- Cenozoic clastic sediments

The deepest aquifer is located above the gas shale horizon.
surface spills ?
• spills at drilling pad, human mistake
• overflow of water pond due to heavy rain track
• spills in transport; car accidents
composition of frac fluid and flow back water
slick water fracturing

- fracturing (>1000 m³ of water per stage), being 99.5 % water & sand – hydraulic hammer & agent stopping frack closure + 0.5 % chemical additives (mainly friction reducers – polymers, previously diesel fuel with benzenes, gelling agent, breaker, acid, biocide, others)
- flow back water – additionally rock debris, natural formation brines
water use – does fracturing consumes reserves of aquifers ?
# Water Consumption in 4 Major Shale Plays

<table>
<thead>
<tr>
<th>Shale Gas Play</th>
<th>Public Supply</th>
<th>Industrial and Mining</th>
<th>Power Generation</th>
<th>Irrigation</th>
<th>Livestock</th>
<th>Shale Gas</th>
<th>Total Water Use (Bbl/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barnett Shale</td>
<td>82.70%</td>
<td>4.50%</td>
<td>3.70%</td>
<td>6.30%</td>
<td>2.30%</td>
<td>0.40%</td>
<td>11.15</td>
</tr>
<tr>
<td>Fayetteville Shale</td>
<td>2.30%</td>
<td>1.10%</td>
<td>33.30%</td>
<td>62.90%</td>
<td>0.30%</td>
<td>0.10%</td>
<td>31.9</td>
</tr>
<tr>
<td>Haynesville Shale</td>
<td>45.90%</td>
<td>27.20%</td>
<td>13.50%</td>
<td>8.50%</td>
<td>4.00%</td>
<td>0.80%</td>
<td>2.15</td>
</tr>
<tr>
<td>Marcellus Shale</td>
<td>11.97%</td>
<td>16.13%</td>
<td>71.70%</td>
<td>0.12%</td>
<td>0.01%</td>
<td>0.06%</td>
<td>85</td>
</tr>
</tbody>
</table>

The diagram illustrates the distribution of water usage across different sectors and the major shale plays. The public sector accounts for 82.3% of water usage, followed by industrial and mining activities at 6.3%, power generation at 3.7%, irrigation at 3.7%, and agriculture at 2.3%. Other industry, including mining, consumes 4.5% of the water, while federal and state government activities take up 5.5%. Shale gas exploration accounts for more than 1% of the water usage.
## Water Consumption

- 1,000-5,000 m³ per one stage used once in well history
- up to 10,000-70,000 m³ per well * several thousand wells
- Warsaw alone consumes ~4-10 times more water than shale gas exploration possibly could in whole Poland
- regulations/permits

## Source of Water for Fracturing

- surface water
- aquifers (generally available)
- shallow formation brines (Cretaceous, Jurassic)
- reuse of flow back waters
- fracking with no water (propane, CO₂ or Nitrogen)
Current aquifer use in Poland:

Available water resources – 13.626 mln m³/year

Used in approx. 11.6%
surface footprints – distraction of landscape?
intensive surface use – early exploration example (New Mexico)
surface use – fracturing

- dense grid of production wells; numerous wells – several thousand per basin
- large well pads: 0.5-4 ha; temporary use
- track transport more intensive than in conventional drilling
recultivation of drilling pad after a few months of temporary use

courtesy: Mayka Kennedy, BC Oil & Gas Commission
recultivated drilling pad at production phase

courtesy: Mayka Kennedy, BC Oil & Gas Commission
reduced surface use – multi-well drilling pad

- up to 15 km² exploited from one pad
- 70 pads (2,000-4,000 ha) per 1,000 km²
drilling & track transport
– disturbance for local communities?
surface use concerns – population density

- density of population – agriculture vs industrialized surface; mostly ~20-60 p/km², except of Warsaw and Gdansk vicinity
impact of shale gas exploration & production on natural environment

• impact on local communities (track transport, noise, exhausts, lights)
surface use concerns – industrialized areas
• ~200 tracks per fractured wells
• dense network of local roads, generally no need for road construction, however impact of local communities life quality
first shale gas drilling pad in Poland (Łebyń LE-1 well)
courtesy: Kamlesh Parmar, Lane Energy Poland
thank you
greenhouse gases emission

• natural gas – the cleanest fossil fuel in combustion
• energy mix of Poland based on coal
• methane emissions:
  – pipelines & compressor stations; newer infrastructure and shorter transport – better
  – venting of gas during exploration, mainly fracturing
  regulation in Poland requires flaring
energy mix of Poland – based on hard coal and lignite

- natural gas: 14%
- oil: 21%
- lignite: 13%
- hard coal: 46%
- other: 6%

The structure of electricity production: 2006 and 2030

- 2006: 147,7 TW·h
- 2030: 201,8 TW·h
- Węgiel kamienny: 21,0%
- Węgiel brunatny: 36%
- OZE: 18,8%
- Produkty nafowe: 1,5%
- Gaz ziemny: 0,6%
- Pozostałe: 6,5%
water consumption (Barnett shale, Texas)

- Public sector: 82.3%
- Irrigation: 6.3%
- Agriculture: 2.3%
- Industry: 5.5%
- Energy: 3.7%
- Other industry (including mining): 4.5%
- Shale gas exploration: >1%

Percentages of water consumption by sector.
reduced surface use – multi-well drilling pad
cumulative water use for energy production

source: Chesapeake Energy 2010
### slick water fracturing

<table>
<thead>
<tr>
<th>Additive Type</th>
<th>Main Compound(s)</th>
<th>Purpose</th>
<th>Common Use of Main Compound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diluted Acid (15%)</td>
<td>Hydrochloric acid or muriatic acid</td>
<td>Help dissolve minerals and initiate cracks in the rock</td>
<td>Swimming pool chemical and cleaner</td>
</tr>
<tr>
<td>Biocide</td>
<td>Glutaraldehyde</td>
<td>Eliminates bacteria in the water that produce corrosive byproducts</td>
<td>Disinfectant; sterilize medical and dental equipment</td>
</tr>
<tr>
<td>Breaker</td>
<td>Ammonium persulfate</td>
<td>Allows a delayed break down of the gel polymer chains</td>
<td>Bleaching agent in detergent and hair cosmetics, manufacture of household plastics</td>
</tr>
<tr>
<td>Corrosion Inhibitor</td>
<td>N,n-dimethyl formamide</td>
<td>Prevents the corrosion of the pipe</td>
<td>Used in pharmaceuticals, acrylic fibers, plastics</td>
</tr>
<tr>
<td>Crosslinker</td>
<td>Borate salts</td>
<td>Maintains fluid viscosity as temperature increases</td>
<td>Laundry detergents, hand soaps, and cosmetics</td>
</tr>
<tr>
<td>Friction Reducer</td>
<td>Polyacrylamide</td>
<td>Minimizes friction between the fluid and the pipe</td>
<td>Water treatment, soil conditioner</td>
</tr>
<tr>
<td></td>
<td>Mineral oil</td>
<td></td>
<td>Make-up remover, laxatives, and candy</td>
</tr>
<tr>
<td>Gel</td>
<td>Guar gum or hydroxyethyl cellulose</td>
<td>Thickens the water in order to suspend the sand</td>
<td>Cosmetics, toothpaste, sauces, baked goods, ice cream</td>
</tr>
<tr>
<td>Iron Control</td>
<td>Citric acid</td>
<td>Prevents precipitation of metal oxides</td>
<td>Food additive, flavoring in food and beverages; Lemon Juice ~7% Citric Acid</td>
</tr>
<tr>
<td>KCl</td>
<td>Potassium chloride</td>
<td>Creates a brine carrier fluid</td>
<td>Low sodium table salt substitute</td>
</tr>
<tr>
<td>Oxygen Scavenger</td>
<td>Ammonium bisulfite</td>
<td>Removes oxygen from the water to protect the pipe from corrosion</td>
<td>Cosmetics, food and beverage processing, water treatment</td>
</tr>
<tr>
<td>pH Adjusting Agent</td>
<td>Sodium or potassium carbonate</td>
<td>Maintains the effectiveness of other components, such as crosslinkers</td>
<td>Washing soda, detergents, soap, water softener, glass and ceramics</td>
</tr>
<tr>
<td>Proppant</td>
<td>Silica, quartz sand</td>
<td>Allows the fractures to remain open so the gas can escape</td>
<td>Drinking water filtration, play sand, concrete, brick mortar</td>
</tr>
<tr>
<td>Scale Inhibitor</td>
<td>Ethylene glycol</td>
<td>Prevents scale deposits in the pipe</td>
<td>Automotive antifreeze, household cleansers, and de-icing agent</td>
</tr>
<tr>
<td>Surfactant</td>
<td>Isopropanol</td>
<td>Used to increase the viscosity of the fracture fluid</td>
<td>Glass cleaner, antiperspirant and hair color</td>
</tr>
</tbody>
</table>

Note: The specific compounds used in a given fracturing operation will vary depending on company preference, source water quality and site-specific characteristics of the target formation. The compounds shown above are representative of the major compounds used in hydraulic fracturing of gas shales.