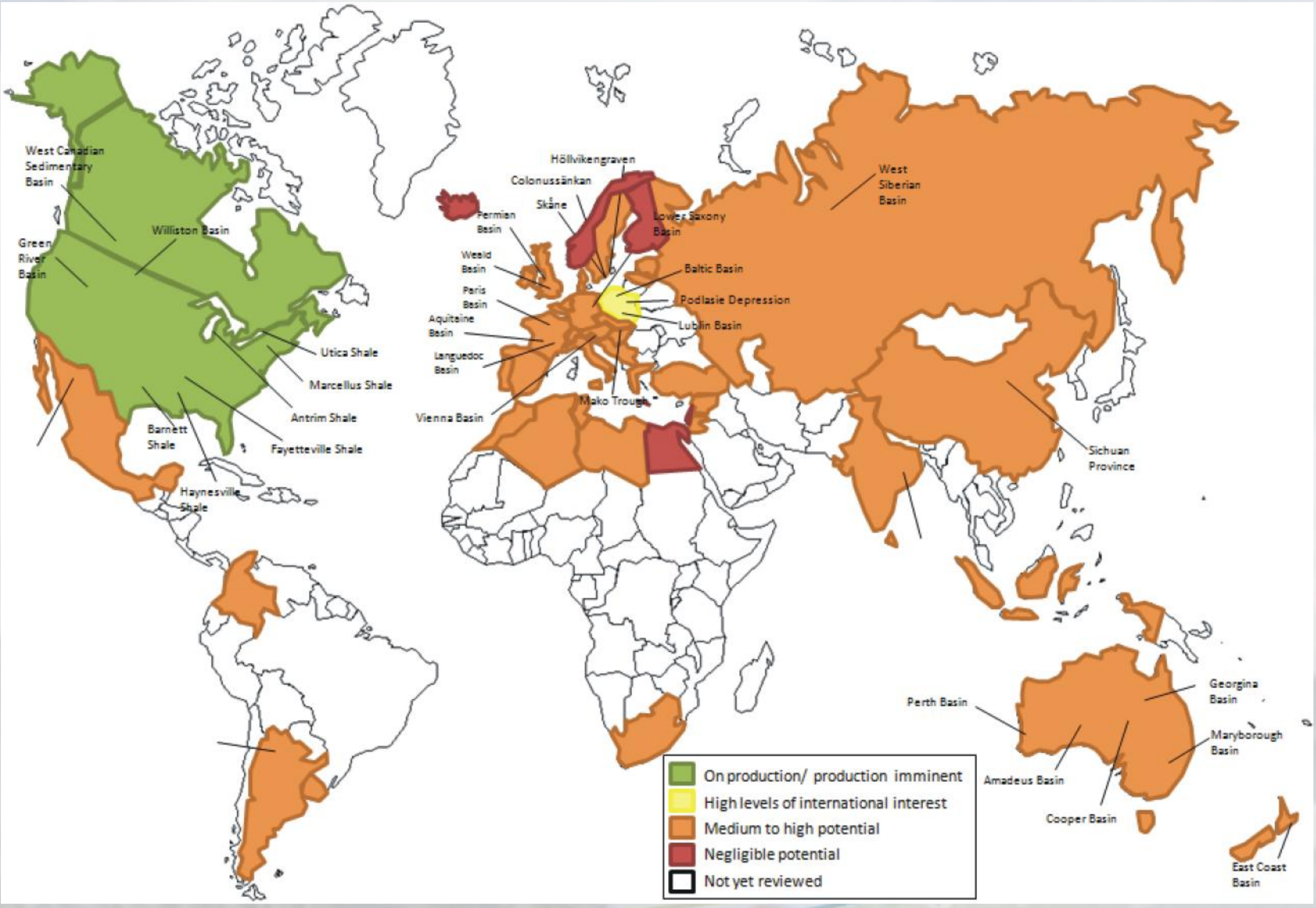
Polish Geological Institute
Polish Geological Survey

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

Paweł Poprawa

Shale gas – energy alternative or environmental threat, Sophia, 11.11.2011

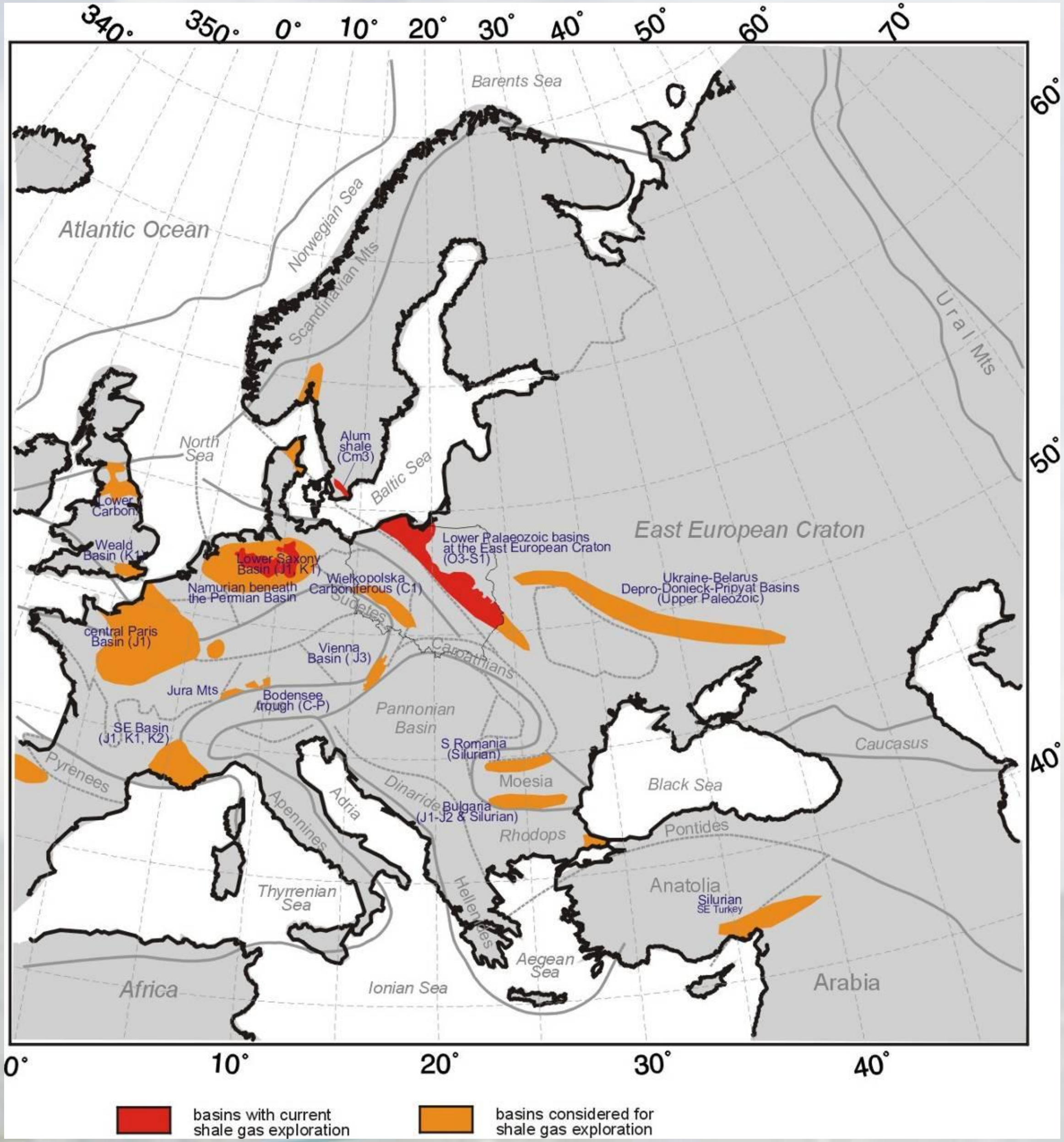
global shale gas potential (after: PETRENEL)



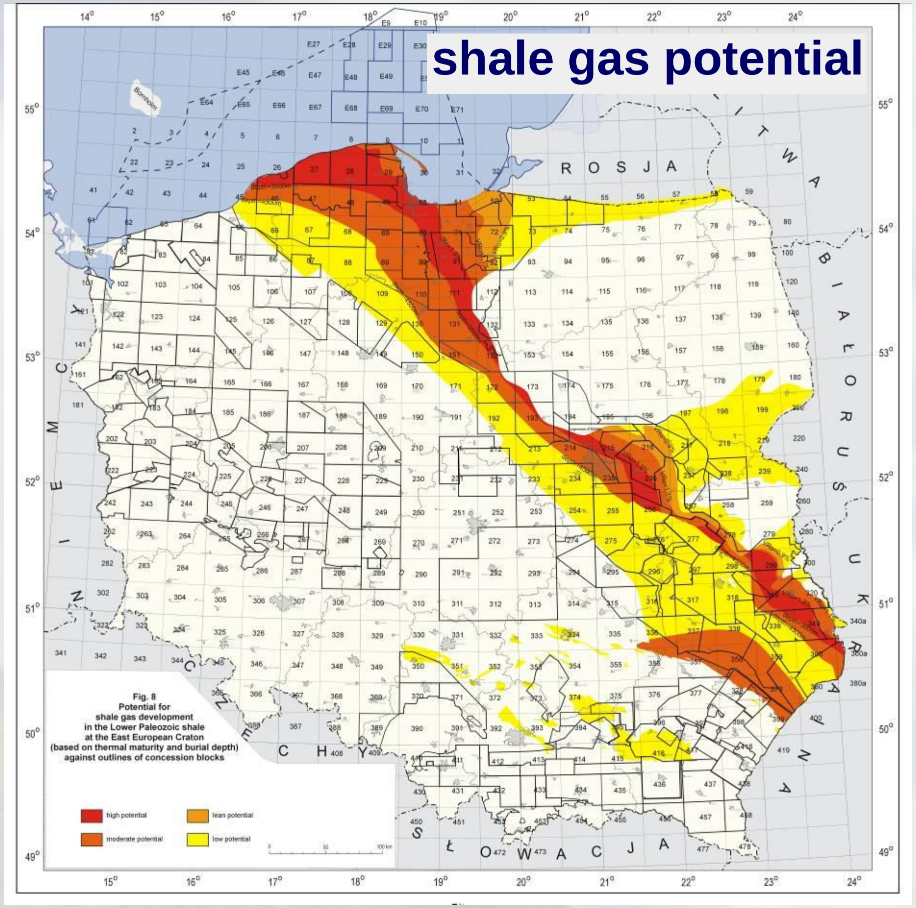
shale gas impact on US economy

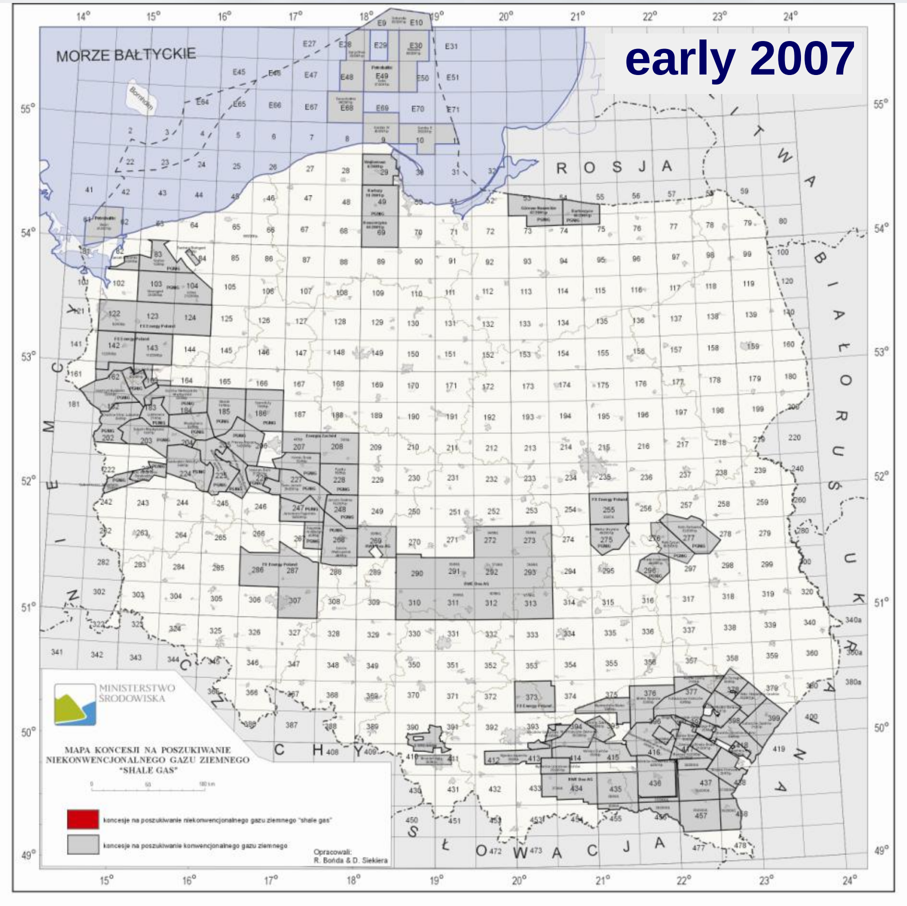
- recently shale gas stands for **~ 25 % US gas production**
- cumulative shale gas investments in US **~80 bln USD/year**
- no import of gas to US – export of LNG gas; **US** become **the biggest gas producer** in the World
- **decrease of gas price in USA** in 2008-2009 – bigger nominal profit than all federal support to US economy
- investment of **1 mln 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

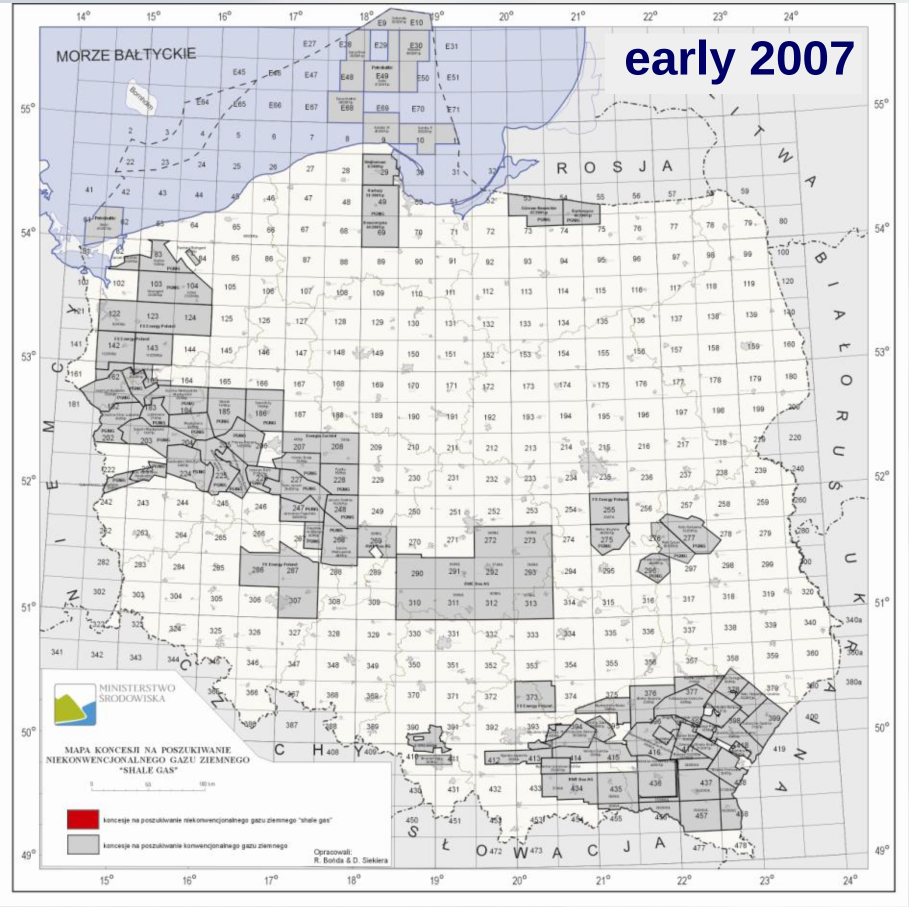


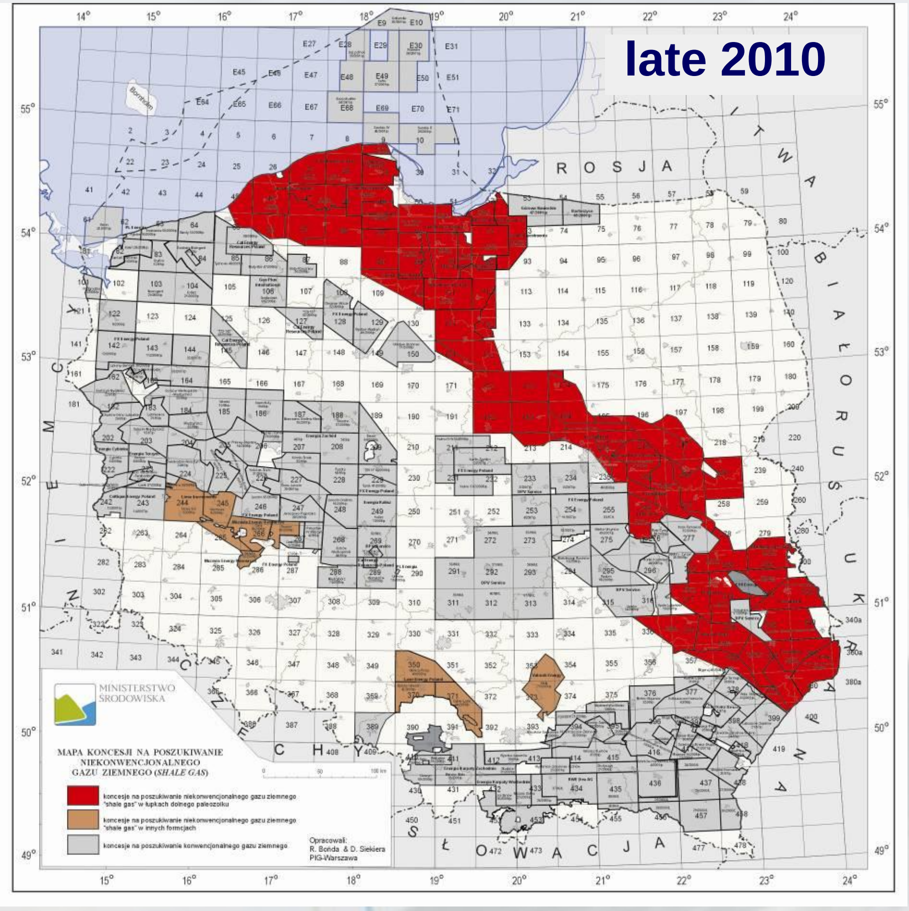
Poland – a rush shale gas market





Poland – a rush shale gas market





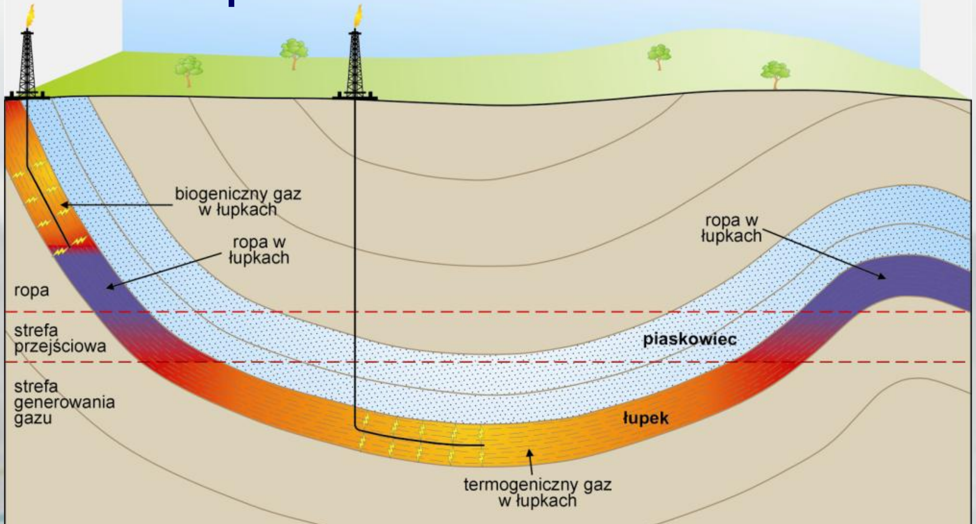
Poland – a rush shale gas market

- >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

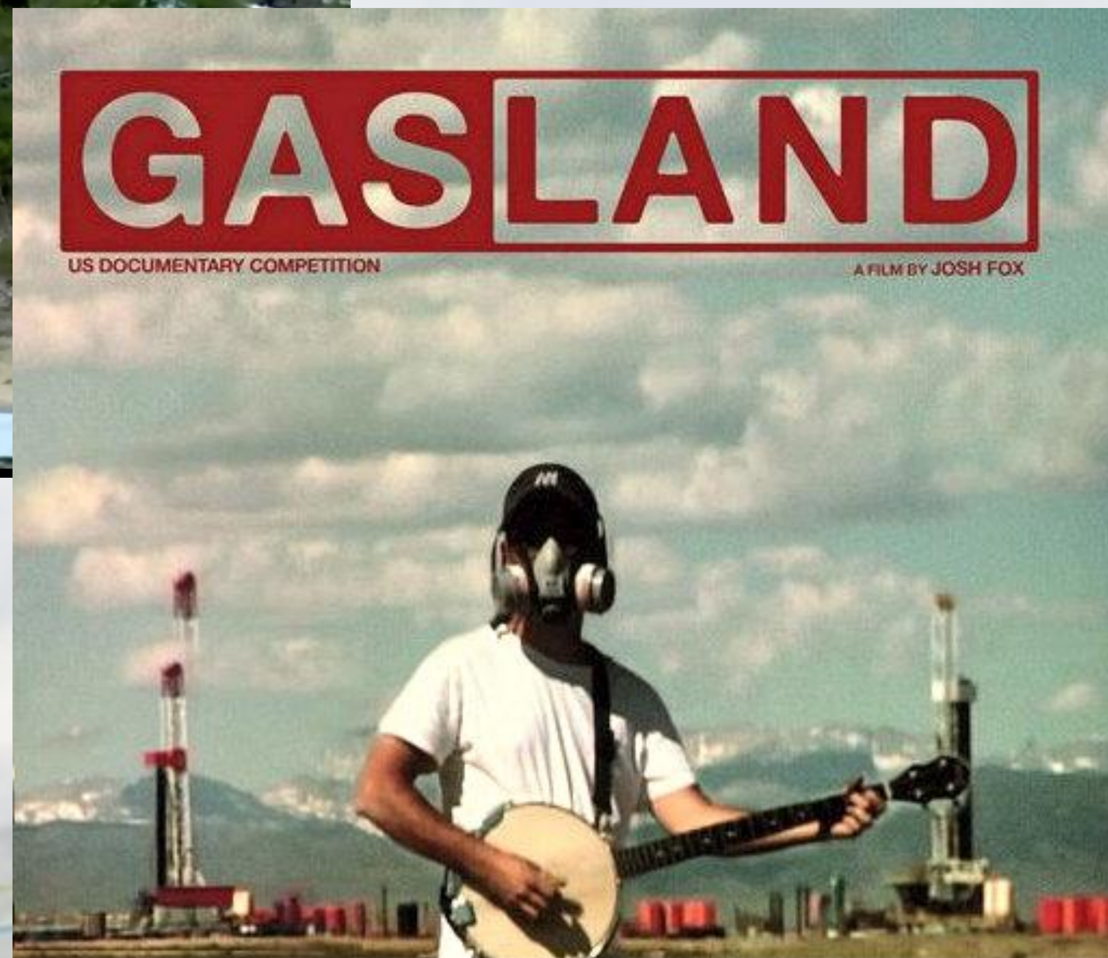
environmental impact

fracturing & flow back waters

- fracturing applied since 1949
- up to 1 million frac jobs were done so far – large experience
- 1.000-5.000 m^3 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



europarltv.eu

shale gas expertise in Poland

- **cooperation/training with US and Canadian public administration & environment protection agencies (EPA, USGS, BCO&GC, etc)**

shale gas expertise in Poland

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- **preliminary environment impact assessment in 2010**

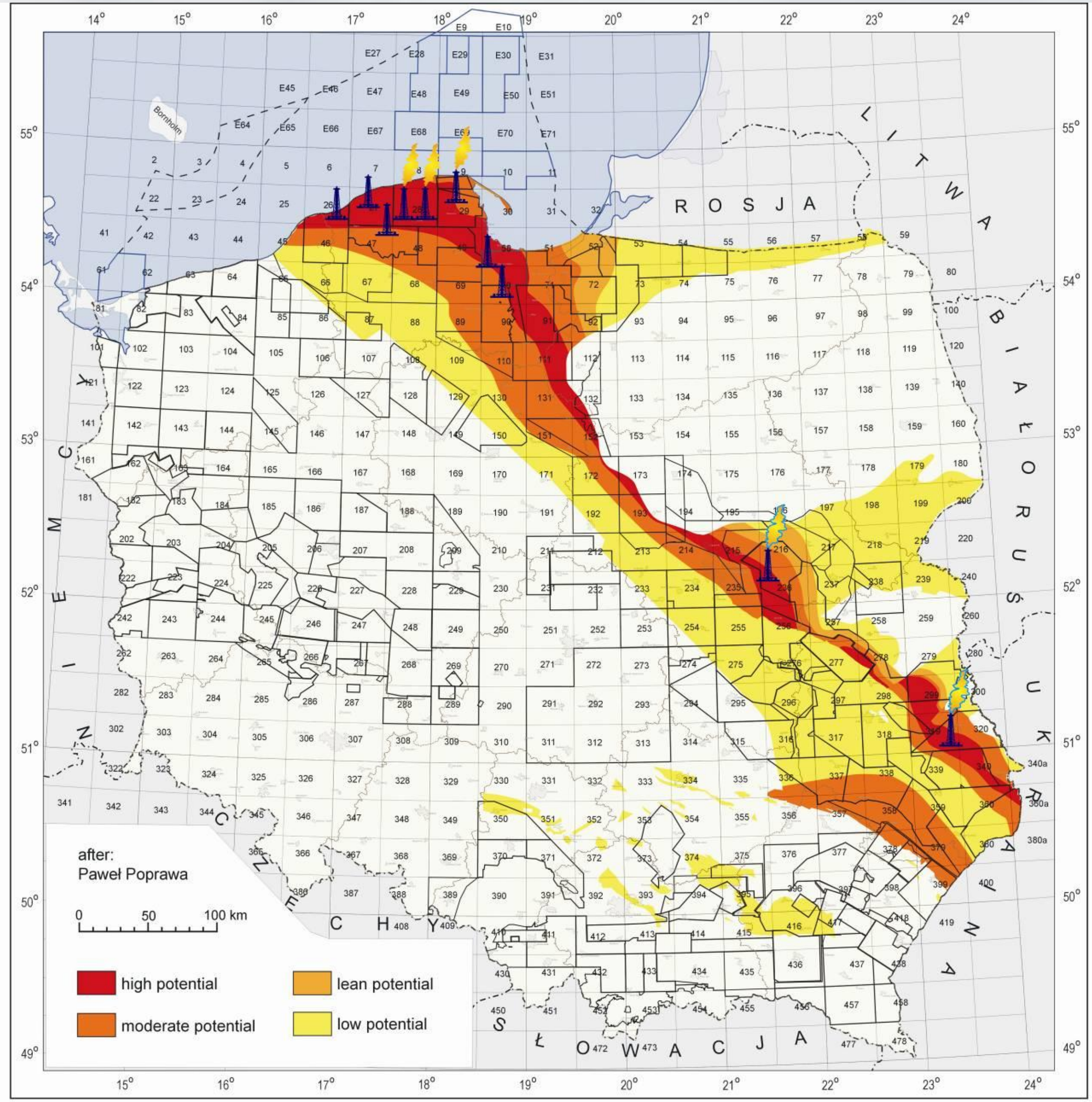
shale gas expertise in Poland

- cooperation/training with US and Canadian public administration & environment protection agencies (EPA, USGS, BCO&GC, etc)
- 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**

shale gas in Poland

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



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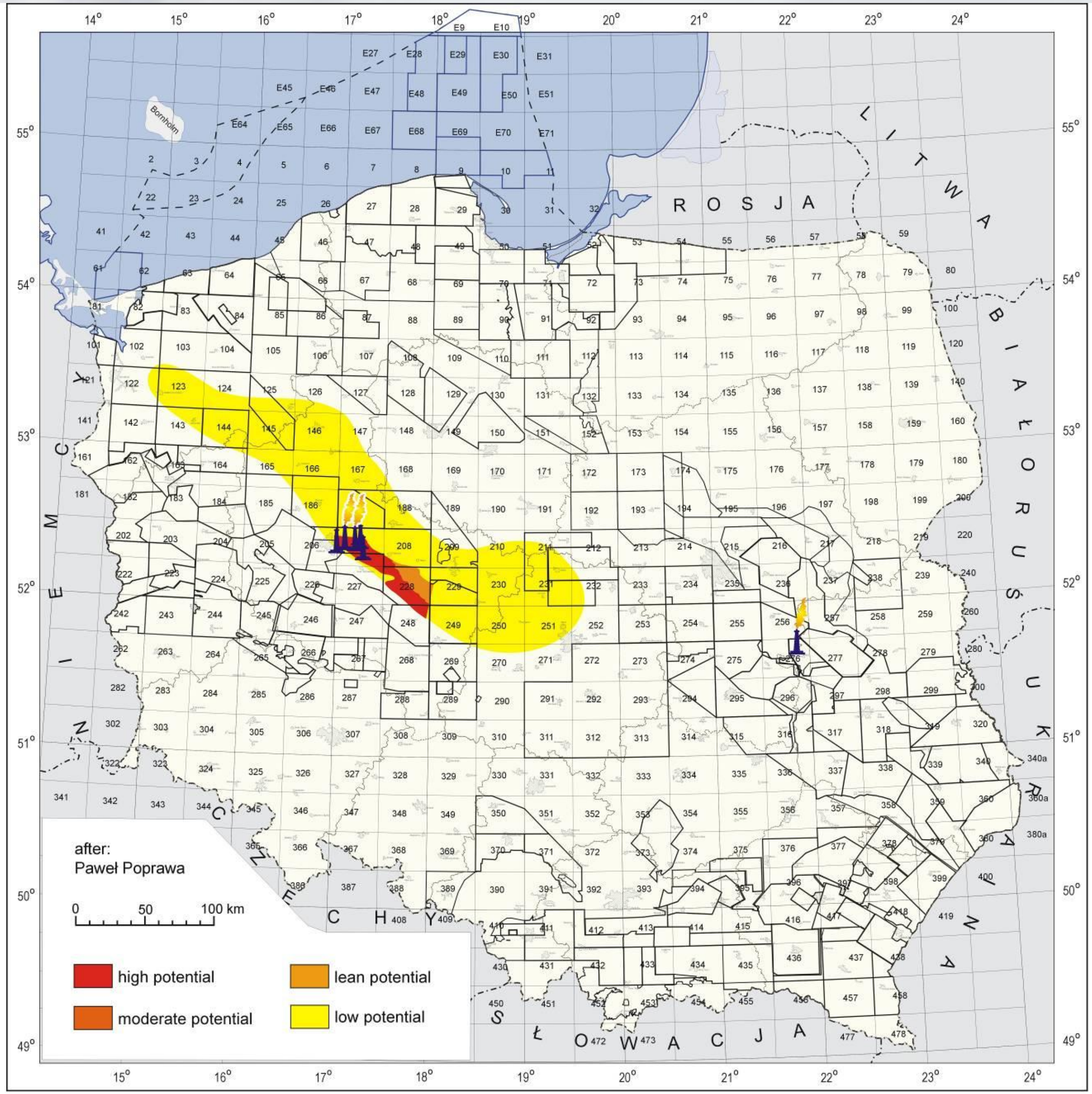
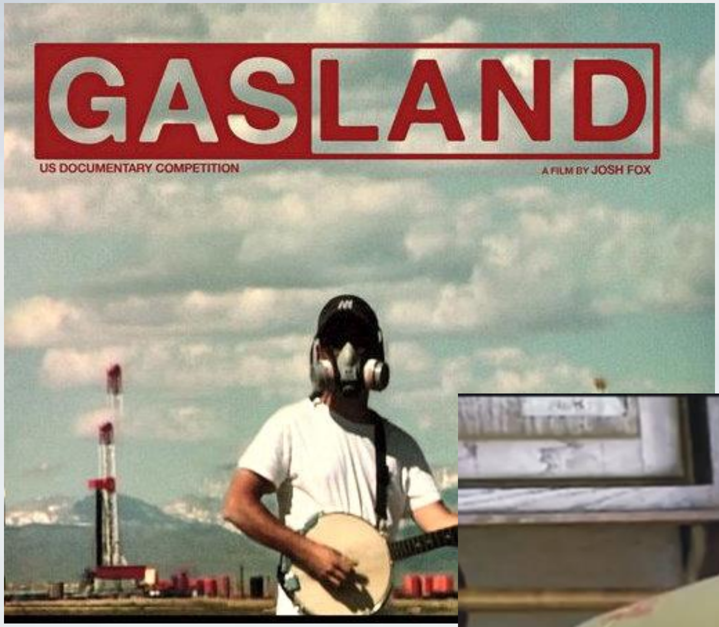
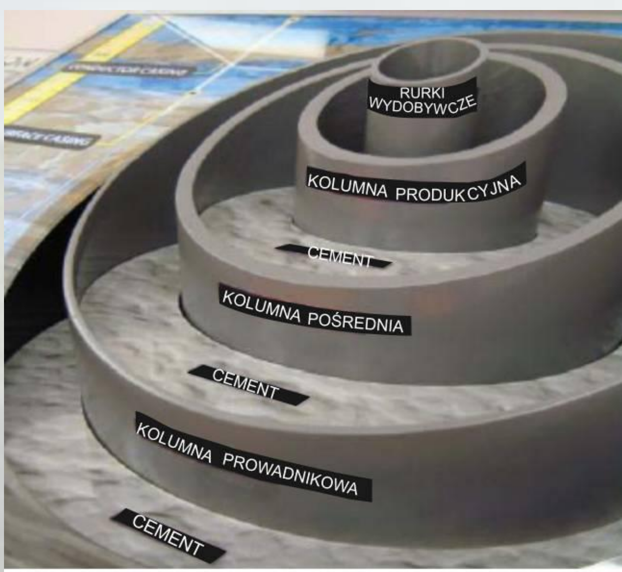


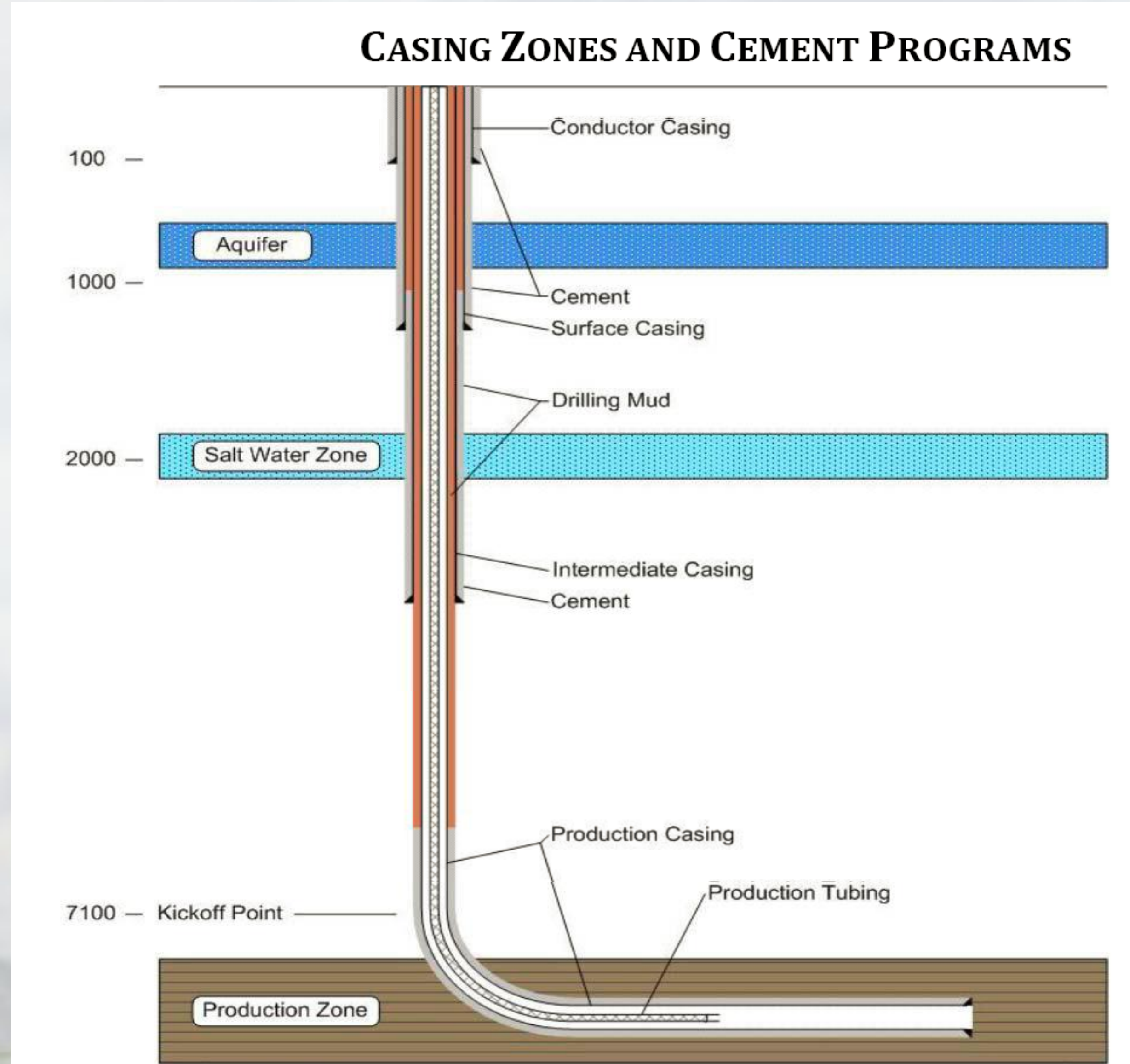
Methane in water taps ?

unverified non-expert concepts with impact on decision makers



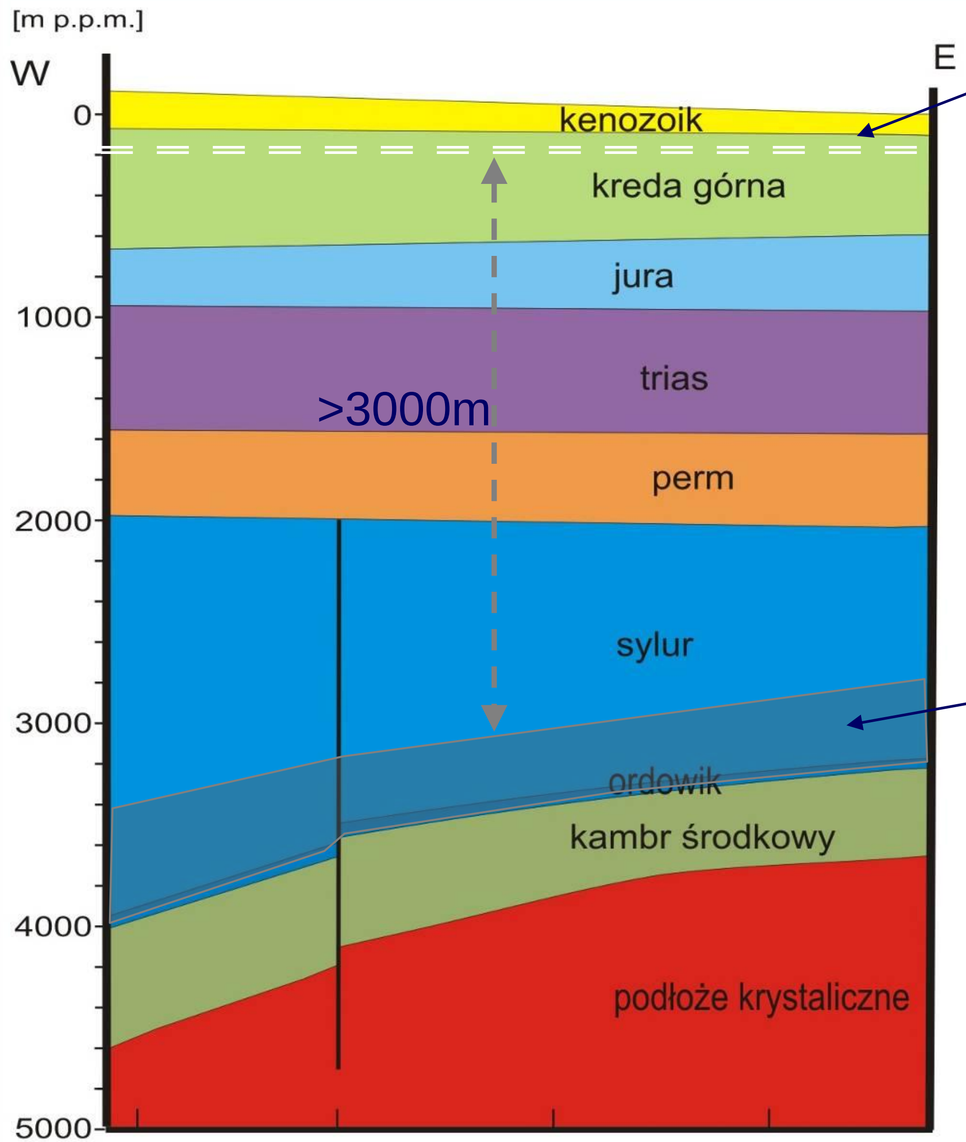
hazard of aquifer contamination during drilling and production?





pollution of aquifers by frac fluid ?

hazard of aquifer contamination during fracturing?



deepest aquifer

Cenozoic clastic sediments

Cretaceous marl

Jurassic sandstone, marl & limestone

Triassic sandstone & mudstone & carbonates

Zechstein evaporites

Upper Silurian shale & mudstone – regional seal

gas shale

Ordovician carbonate & clastic sediments

Cambrian tight sandstone & mudstone

Precambrian crystalline basement

courtesy: Jerzy Hadro

surface spills ?

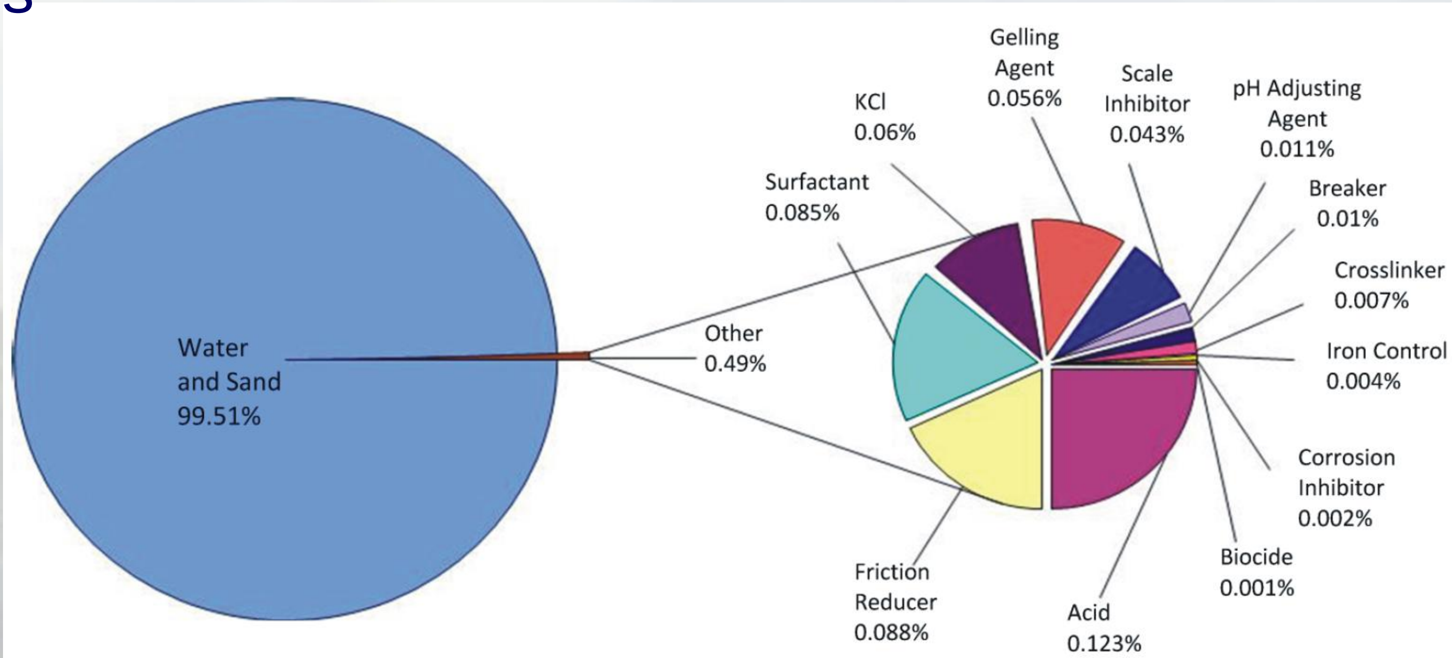
surface spills?

- 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 m^3 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

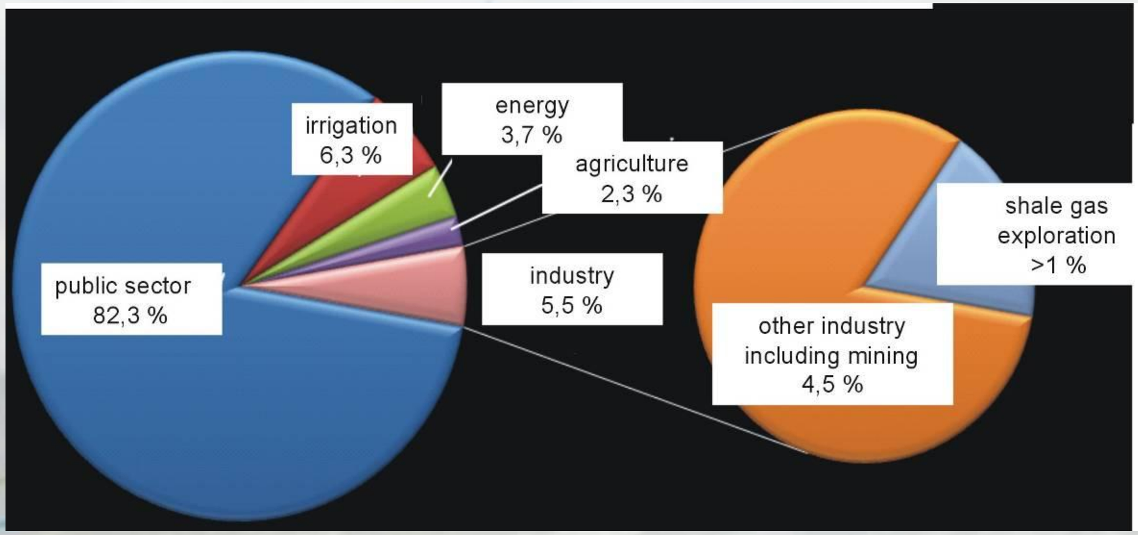


water use – does fracturing consumes reserves of aquifers ?

water use for fracturing

water consumption in 4 major shale plays

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



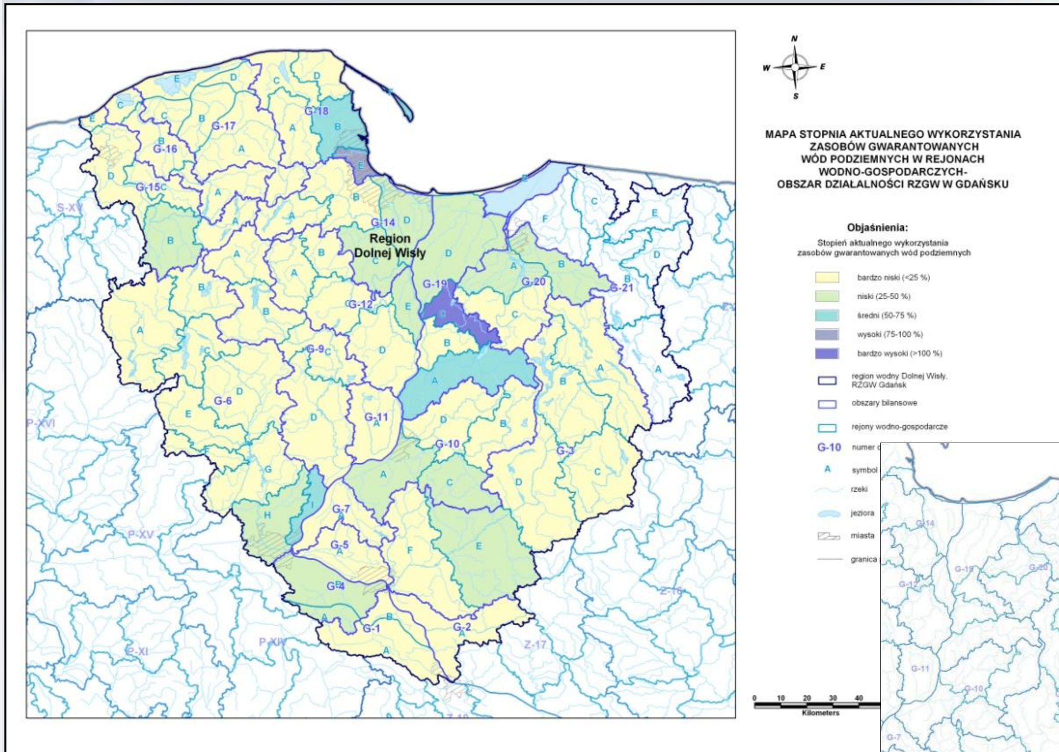
water consumption

- 1.000-5.000 m^3 per one stage used once in well history
- up to 10.000-70.000 m^3 per well * several thousand wells
- Warsaw alone consumes ~4-10 times more water than shale gas exploration possibly could in whole Poland
- regulations/permits

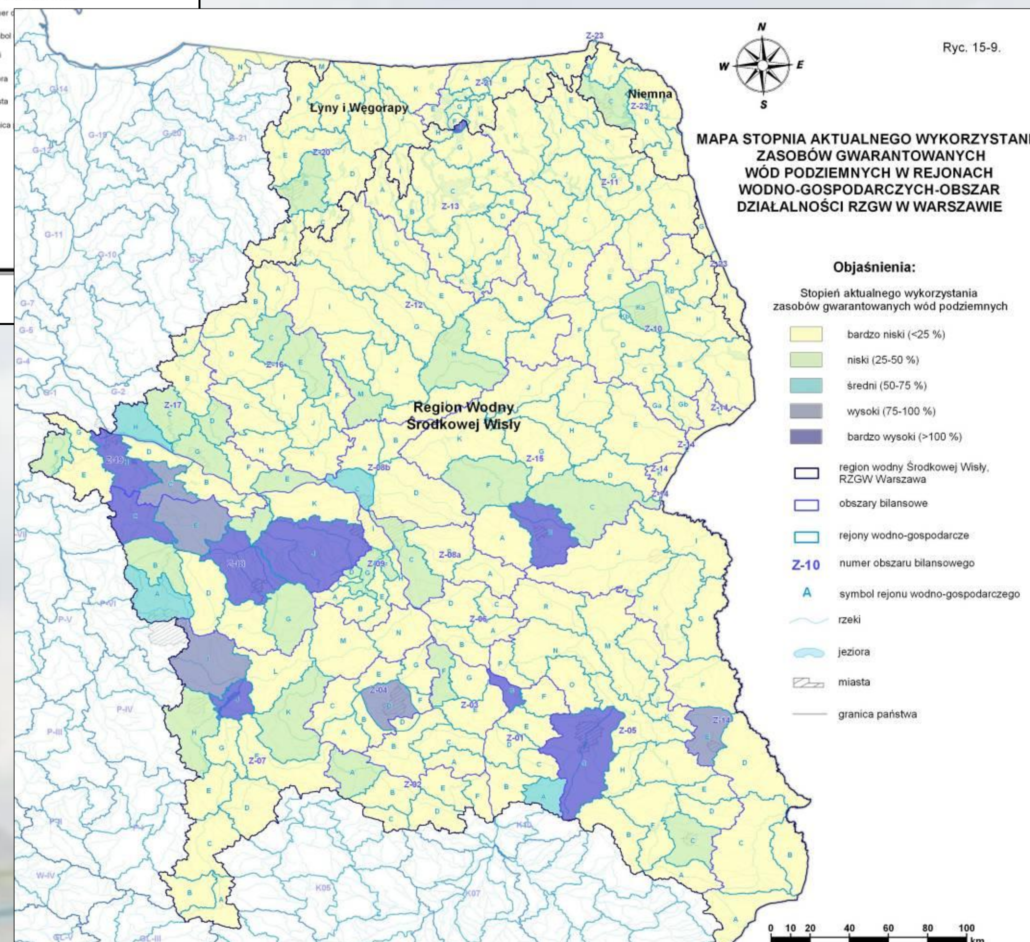
source of water for fracturing

- surface water
- aquifers (generally available)
- shallow formation brines (Cretaceous, Jurassic)
- reuse of flow back waters
- fracking with no water (propane, CO_2 or Nitrogen)

aquifer reserves in Poland



courtesy: Małgorzata Woźnicka



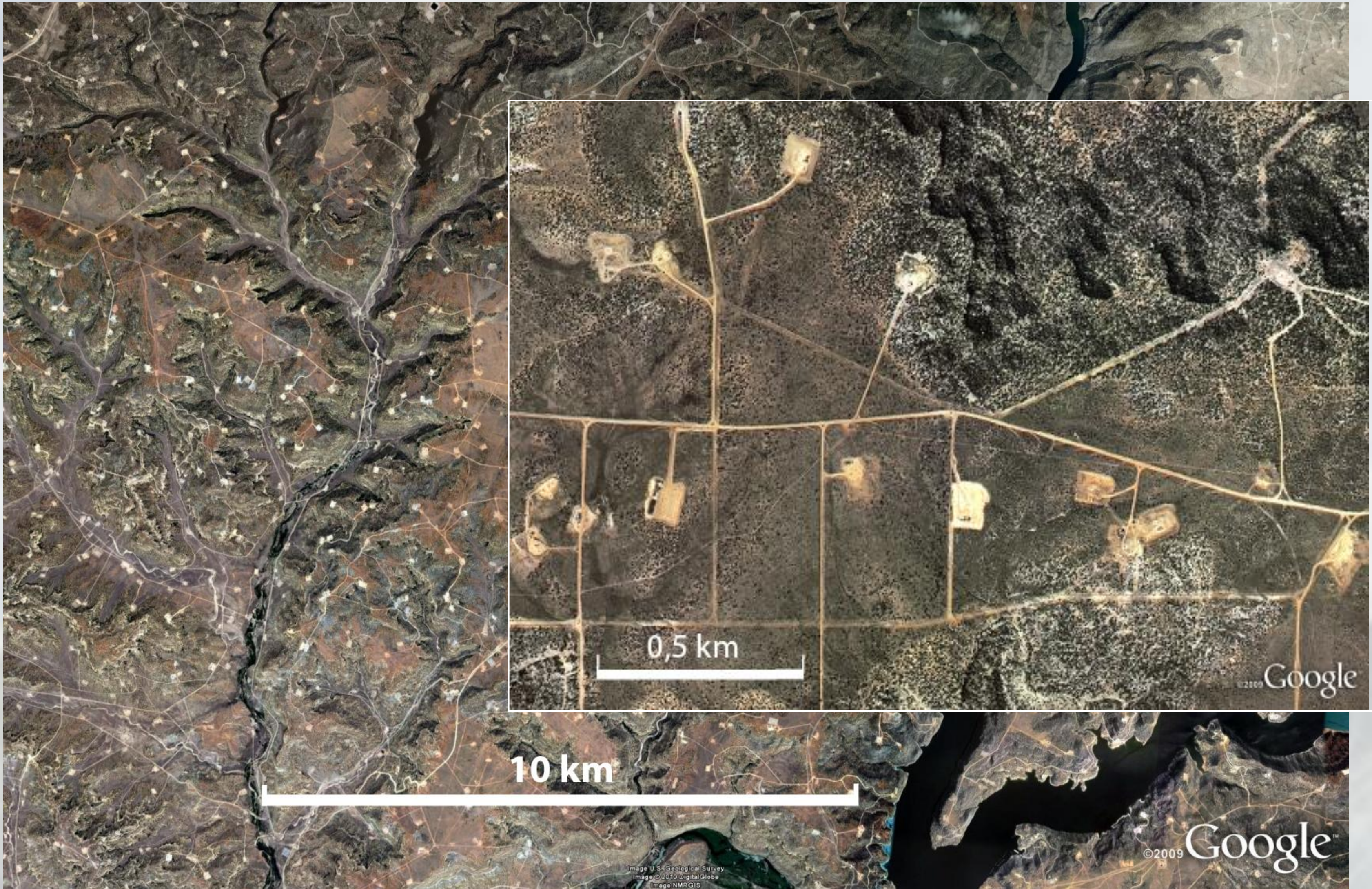
current aquifer use in Poland:

available water resources – 13.626 mln m^3/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

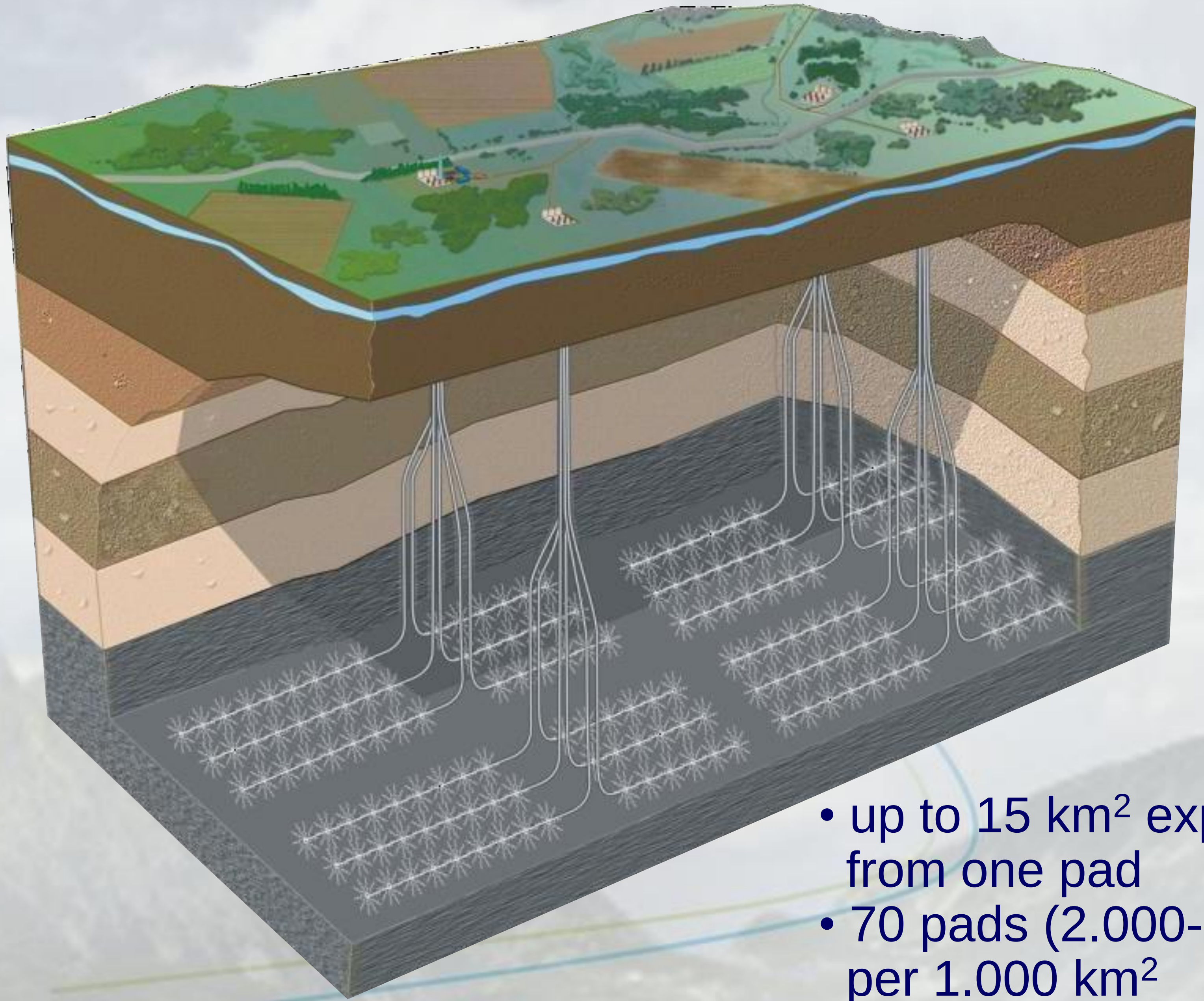
recultivation of drilling pad after a few months of temporary use

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



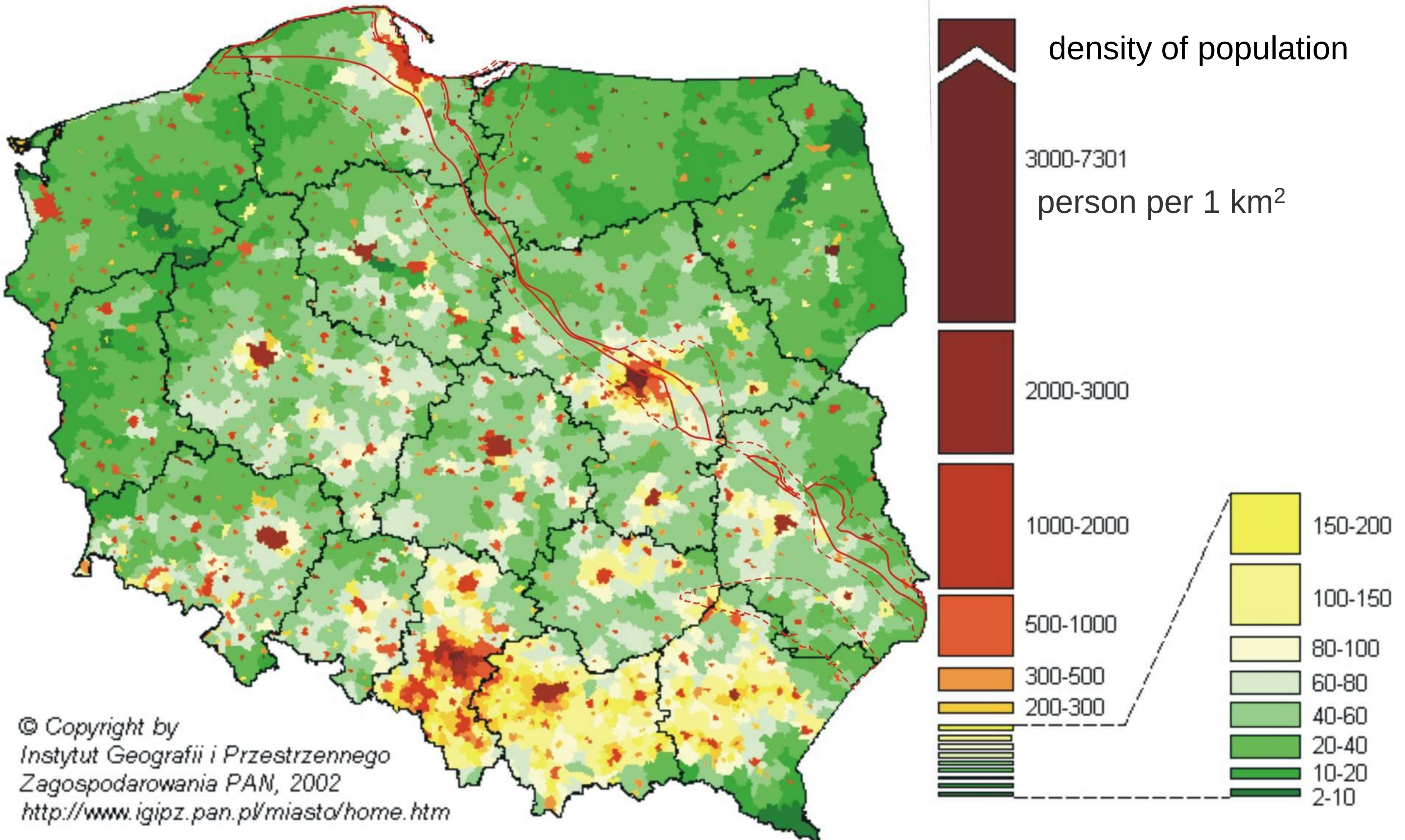
- up to 15 km^2 exploited from one pad
- 70 pads (2.000-4.000 ha) per 1.000 km^2

drilling & track transport

– disturbance for local communities ?

surface use concerns – population density

- density of population – agriculture vs industrialized surface; mostly ~20-60 p/km^2, 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

heavy track transportation

- ~200 tracks per fractured wells
- dense network of local roads, generally no need for road construction,
  however impact of local communities life quality

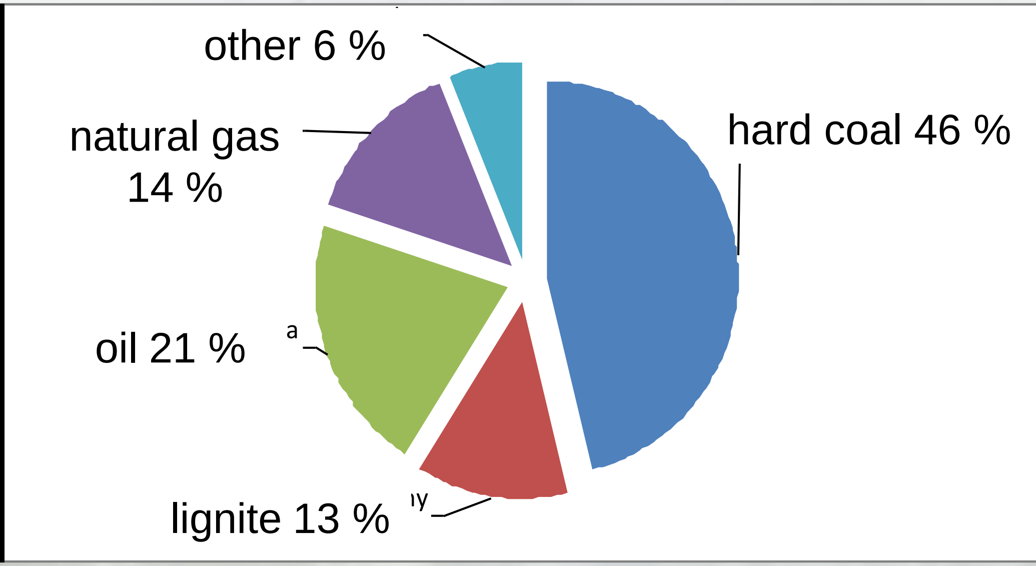
first shale gas drilling pad in Poland (Łebień LE-1 well)

courtesy: Kamlesh Parmar, Lane Energy Poland

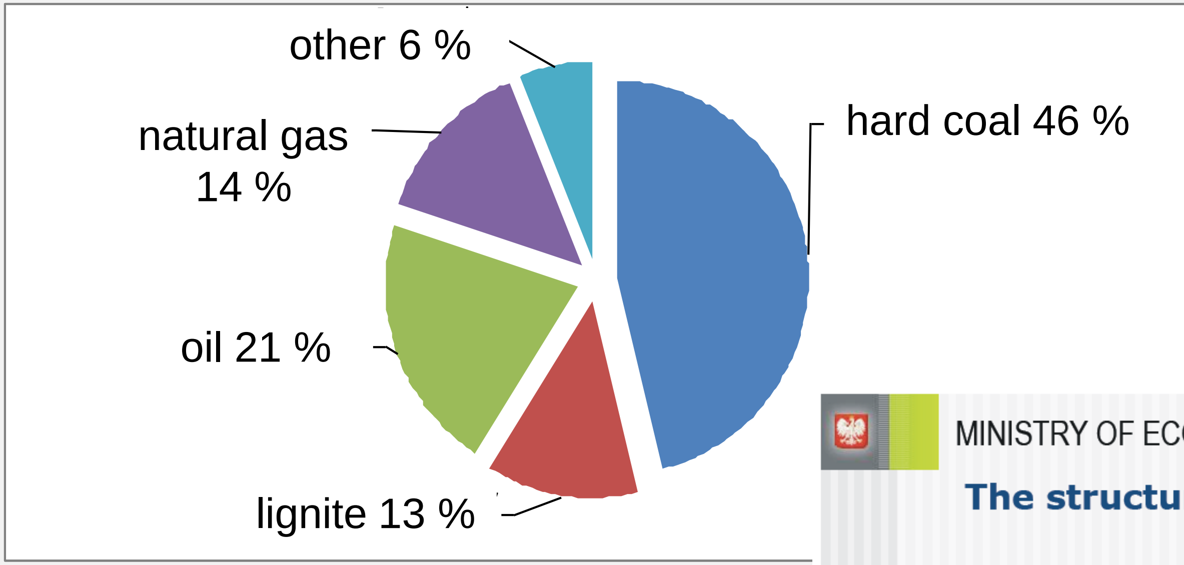
thank you

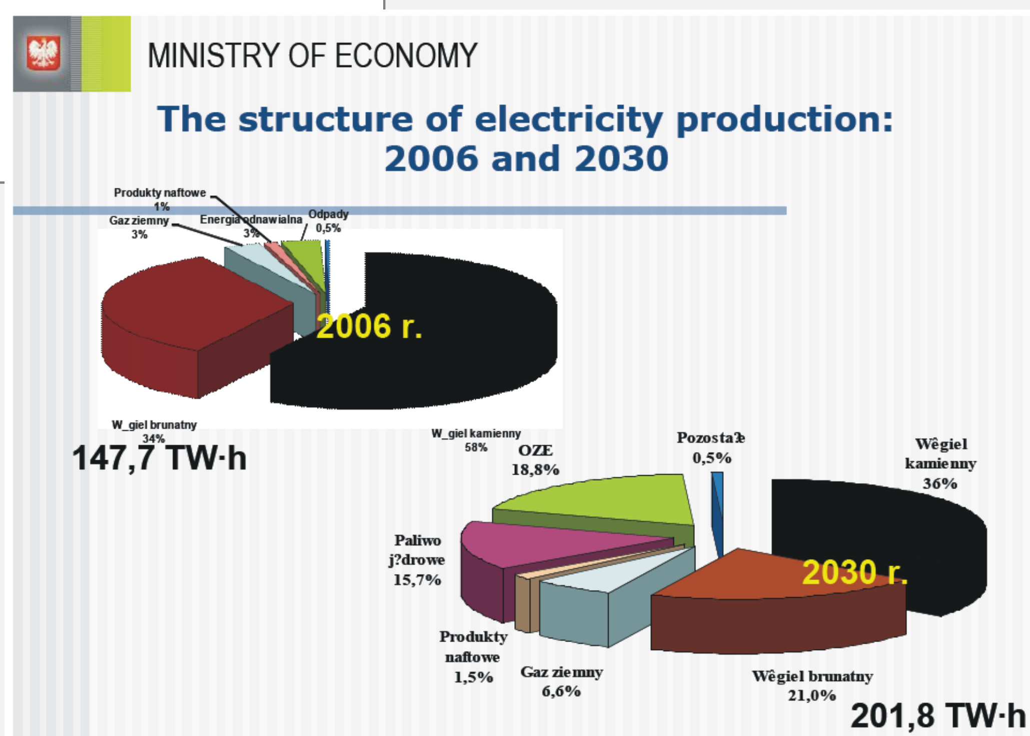
greenhouse gases emission

- 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

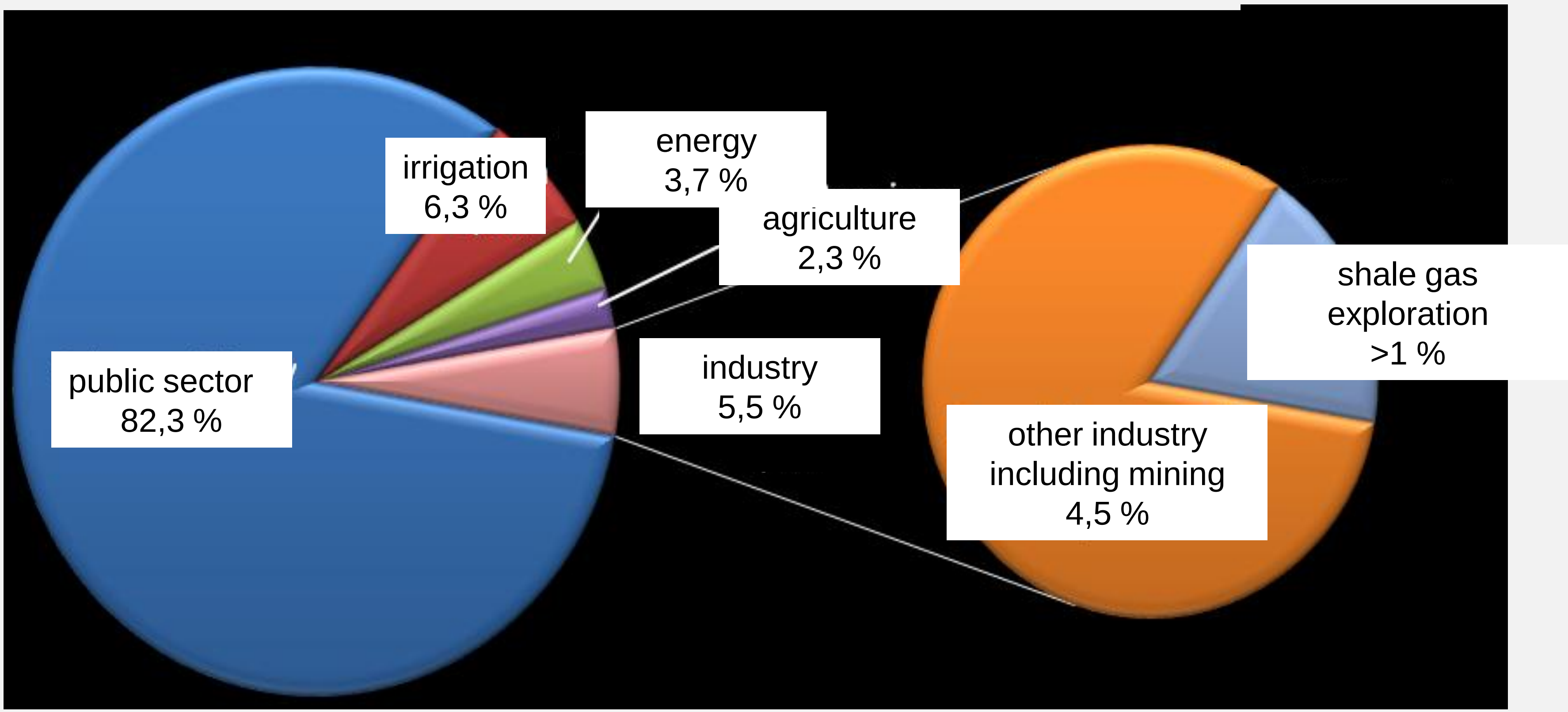


energy mix of Poland – based on hard coal and lignite

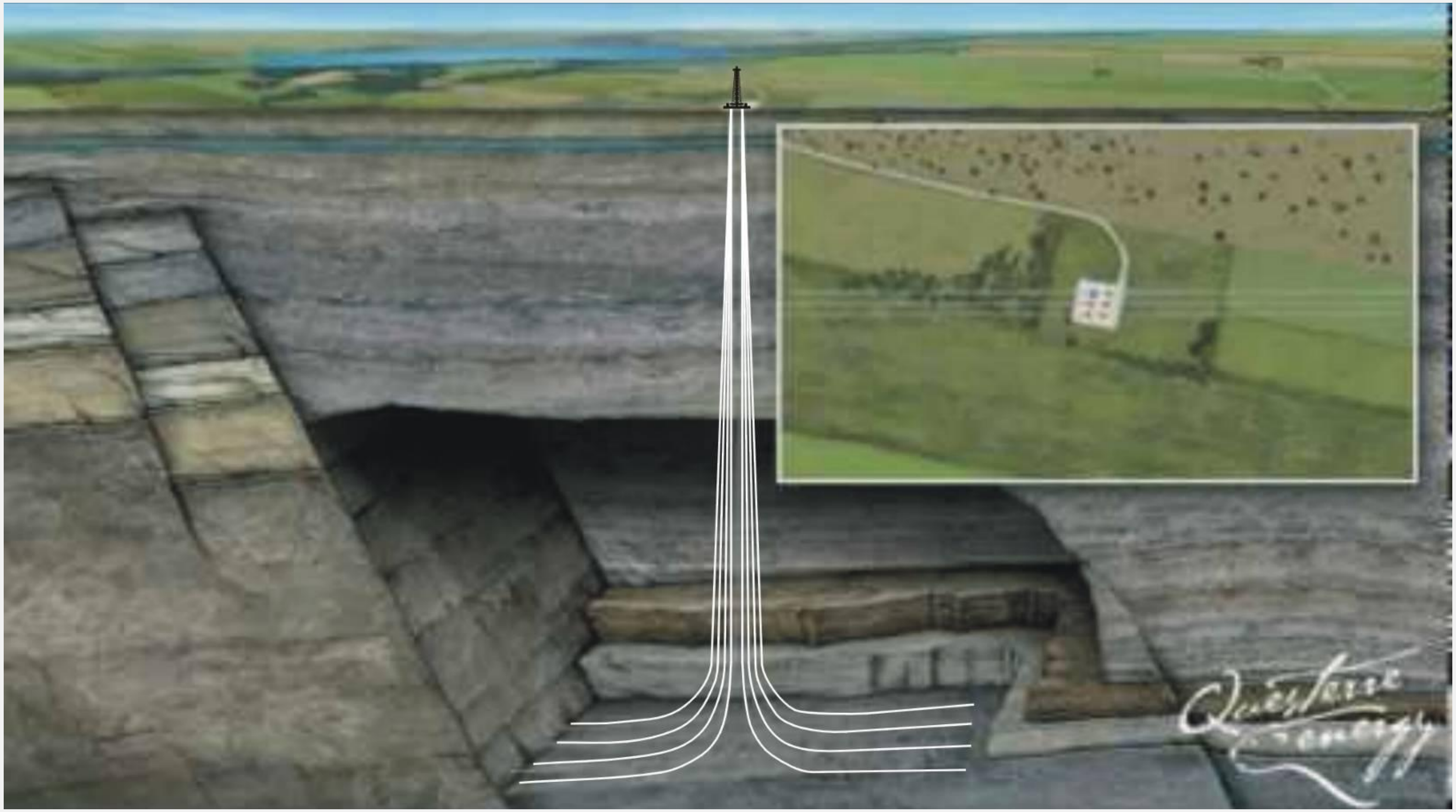




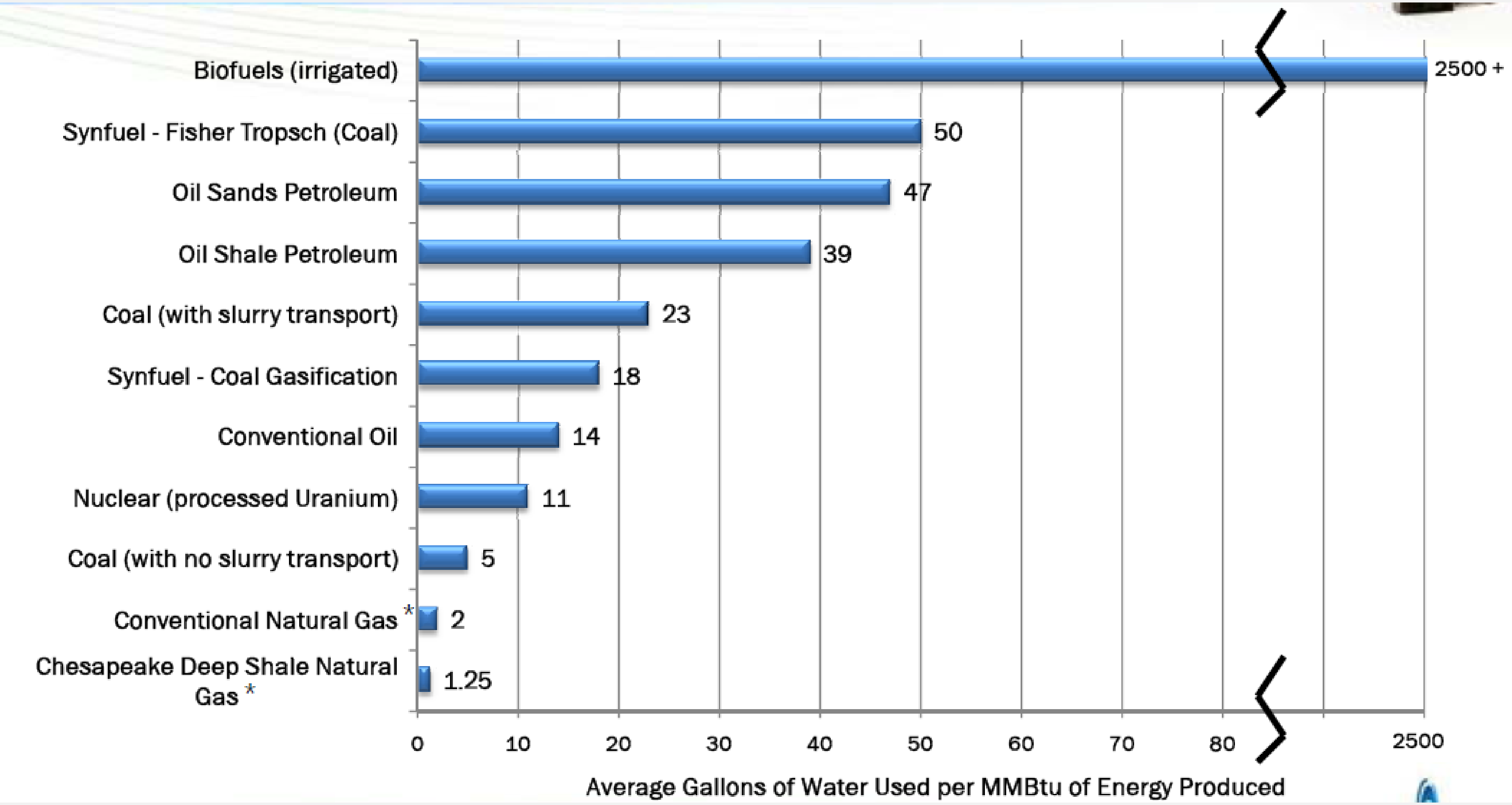
water consumption (Barnett shale, Texas)



reduced surface use – multi-well drilling pad



cumulative water use for energy production



source: Chesapeak Energy 2010

slick water fracturing

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

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.