Shale Gas Recovery
- Appearance vs Reality -

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Myth #1: “Shale gas is developed with a new drilling technology known as hydraulic fracturing”

- Operative word: NEW
- Well stimulation has been safely applied in Western-Europe for more than 50 years
  - Netherlands has 1600 gas wells; 250 hydrofrac treatments (many more in Germany)
- Nothing new in shale stimulation
  - Actually less chemicals, as in first frac treatments
  - Total number of treatments per well is larger, up to 40-60, but in the North Sea wells were treated with 18 frac stages, so no significant difference. Interference between stages is small since laterals are long.
  - Footprint of drilling is larger compared with conventional wells, but impact can be mitigated
Myth #2: “Shale gas recovery pollutes aquifers with gas and frac chemicals”

• Inconceivable that fracture would grow to shallow strata, as supported by frac mapping and fundamental physics
• Pollution Cases in the US:
  – Gas in groundwater: Happened by casing leaks
    • This is not bad luck, but poor design (30 m surface casing and then TD the well)
  – Allegations of fracture fluids in aquifers have all been dismissed
    • Vermillion (Wyoming): Fracture jobs at 300 m depth seemed to give contamination but this was actually due to drilling fluids used in the water wells themselves.
    – Conclusion: ZERO cases of fracture fluid contamination in ground water

• Myth #3: Bad things in the US will necessarily happen in Europe
  – W-European industry has immaculate record regarding protection of ground water
Myth#4: “Shale gas stimulation uses unacceptable amounts of water”

• Stimulations do use large amounts of fluid:
  – Per stage: 1000 m$^3$ of water (100 MT of sand)
• However: even in Texas the total water use for gas well drilling is 1% of total usage.
  – Overall the shale gas industry uses less than 0.5% of total water usage
  – Netherlands has plenty of water sources. Semi-permanent water lines may be useful for reducing footprint.
Myth #5: “Shale gas stimulation causes earthquakes”

- Maximum magnitude of induced earthquakes is non-damaging (e.g. truck driving by)
- Extremely unlikely events: less than 1 in a 100,000 treatments
- Of course, virtually all stimulation treatments cause earthquakes: equivalent to dropping a brick on the floor
No Hazards or Hassle for Local Population?

• Of course drilling causes noise
  – Pad drilling reduces impact
  – After some time only well heads remain

• Many truck loads of materials
  – Appropriate logistics may mitigate nuisance
  – Only tangible hazards related to traffic accidents and surface spills

• Well drilling and stimulation can be done in populated areas: Beverley Hill Fracs
Frac’ing in Beverly Hills 90210

40 oil wells behind Beverly Hills shopping center.
• For drilling and stimulating 10 wells:
  – 3-6 football fields

• Permanent Well Pad:
  – 3 football fields
  – Drains area of 1500 football fields (11 km²)
Why Commission a Shale Gas Study in the Face of Vehement, Irrational Opposition?
- Is the Ministry of Economic Affairs really thinking that anyone will be convinced? -

• Bergermeer Gas Storage could be pushed through after long legal procedures despite popular resistance
  – A government drilling permit is hard to decline by local authorities, if the legal case is well-founded

• Why no chance for Barendrecht CO₂ Sequestration and (Probably) Shale Gas?
What Drives Popular Resistance against Shale Gas?

“TANTUM TIMOR HOMINES INSANIRE FACIT”:

Such is the insanity to which terror can drive mankind

Benedict de Spinoza, (1670)

• Perhaps Spinoza also provides a solution: radical democracy
  – In this respect we can learn from America which is not only a real democracy, but also the local population benefits from gas production

• Change the Narrative of Fear and Resistance:
  – Make people not just stake holder but shareholder in company that holds mineral rights with participation of government and operator
  – Local population obtains veto power
    • Do we want the 3 Billion royalty revenue (10 million per well for 300 wells. With 200,000 adults in license area: 30,000 Euro per family) or stop development?
    • Revenue could go to shareholder dividend or into improving infrastructure: sport, culture, roads.
  – Both cycle of fear and resistance is broken because local population gains control and the vocal opposition is put to the test whether the population will support them if everyone (including less affluent people) can make their own choice between revenue or blocking the gas production
What are the Prospects for Shale Gas Research & Development?

- Although W-European Shale gas Development is unlikely, international shale exploitation will continue and warrants research and development effort
  - International interest remains high
  - Scientific issues are worthwhile to investigate
  - Forget about issues raised by opponents, but investigate reality
Real Issues in Shale Gas Development

• Economics:
  – Cheap drilling and stimulation:
    • 100% capital utilization with ‘factory’ drilling

• Physics of Unconventional Gas Recovery and Issues in Shale Recovery:
  – What is drainage?
    • Initially 2% in Barnett, but some projects reached 50%. On average currently estimated between 15-35%
    • Resource coverage with waterfracs
    • Optimizing lateral depth, initiation points
  – Fracture Networks in the Field and Lab and the relation with seismicity
    • Seismicity related to productivity?
Hydro-Frac Seismicity

• Almost all hydraulic fractures are associated with micro-seismicity: magnitude <-2 ML
  – Very few documented cases of stronger seismic events:
    • Southern Oklahoma: magnitude 1.9 ML in 1979 and recently magnitude 2.8 MD
    • Comparable to Bowland Shale: 2.3 ML at 3 km
  – However:
    • Stronger seismicity when injecting into faults
    • Geothermal stimulation (targeting faults) shows often stronger seismicity
Microseisms: What Is It?

- A Microseism Is Literally A Micro-Earthquake. Microseisms That Occur During Hydraulic Fracturing Are Caused By:
  - Changes In Stress And Pressure As A Result Of The Treatment
  - By Movement Along Induced Fracture Planes Where Hindered By Irregularities

![Diagram](image-url)
Downhole Microseismic Monitoring

- Microseismic Monitoring is Applied Earthquake Seismology (Seismology 101)
  - Based on principles known for decades
  - Has been used since mid-1970's (Hot Dry Rock)
  - Primary difference is the use of a downhole array

Typically 12-3C level @ 40 ft

Observation Distance
Depends on Seismic Attenuation

Observation Well
Treatment Well
Las Alamos Hot Dry Rock Results

Murphy, et al., 1986, Hydraulic Fracturing of Jointed Formations, SPE 14088.
Complexity In WaterFracs

Waterfracs Can Potentially Add A Much Higher Level Of Complexity To Fracture Behavior
- Network
- Killed Wells
1990’s – Pinnacle Technologies developed Hydraulic Fracture Mapping Technology

Hydraulic fracture induces a characteristic deformation pattern – magnitude ~ earth-tides

Induced tilt reflects the geometry and orientation of created hydraulic fracture
Mapped microseismic height for Marcellus shale

- Top: shallowest microseism; Bottom: deepest microseism
- Aquifers: USGS deepest water wells by county

Smallest height growth at shallow depths

Boxtel Posidonia: 11,500 ft
Hydro-fracture Stimulation Monitored in Various Settings:
Fault activation (at constant distance) is much stronger.
Triaxial load frame for Physical Model Tests
Splitting of Fracture at High Stress Difference

Stress 20 and 16 MPa

Stress 20 and 4 MPa
Shear Fractures growing to Hydro-fracture

Instead of fissures opened by a hydro-frac, shear fractures may be activated in tectonic conditions.
Fracture Net Works and Fracture Conductivity

• Barnett fracture mapping showed wide networks
  – The Barnett formation has almost isotropic horizontal stress
  – Most other plays have much more planar fractures
    • This is likely caused by rock fabric and larger stress anisotropy

• Bowland shale in England:
  – Very large stress contrast between minimum and maximum horizontal stress
  – Still, gas was produced and well deliverability looks promising

• Potential explanation:
  – With anisotropic stress, the fracture networks are planar, but more conductive due to surface roughness

• Evolution of technology:
  – More and more stages are pumped per lateral and with clever interaction between neighbouring wells, the best drainage is obtained.
Conclusions

• Little chance of shale gas development in W-Europe
  – Probably shale gas revolution requires revolution in governance of marginal gas production:
    • Giving control and fair compensation to local population for the impact of gas production on their communities

• In the rest of the world there are many opportunities in Shale Recovery:
  – N-Africa, E-Europe and especially Russia have gigantic resources. Active exploration in China and even Saudi-Arabia
  – Real research issues:
    • What determines reservoir contact?
    • Impact of discontinuities
    • Optimizing drainage and EOR