How Sweet is European Shale? A Story about the Uncertain Potential, Problematic Recovery and Public Concerns of Shale Gas Development in Europe*

Jan ter Heege[1]

Search and Discovery Article #70381 (2019)**
Posted February 18, 2019

*Adapted from oral presentation given at 2018 AAPG Middle East Region, Shale Gas Evolution Symposium, Manama, Bahrain, December 11-13, 2018
 DOI:10.1306/70381Heege2019

[1]TNO Applied Geosciences, Utrecht, The Netherlands (jan.terheege@tno.nl)

Abstract

Currently, shale gas exploration and exploitation in Europe is in an ambiguous arena. Poland once actively pursued shale gas motivated by the desire to remain independent of Russian gas. Shale is explored and drilled in England where proponents are looking for a secure energy supply by developing shale as a reliable and affordable domestic source of energy. For most other European countries, perceptions towards oil and gas extraction from shales are ambiguous. Concerns about environmental footprint have motivated most European countries in postponing or banning shale gas exploitation. Production of gas and oil from shales has proven to be a game changer for the energy market in North America, and most wells have been drilled in the U.S. However, most potential oil and gas resources are located elsewhere. Total potential resource located in the many European shale basins may equal the resources in the U.S. However, where U.S. shale operations have become more and more efficient, attempts to commercially recover gas from Polish shales have not (yet) been successful. Public concerns are mainly related to impacts on local environments and global climate footprint. While focus is on the subsurface effects of hydraulic fracturing and CO_2 emissions, recent studies suggest a bigger role for well construction and methane emissions in determining impacts and risks. This presentation covers both geological and environmental aspects of potential shale gas exploitation in Europe, focusing on key lessons learned from North America, current status in Europe, and main showstoppers hampering development.

Selected References

Anthonsen, K.L., S. Schovsbo, and P. Britze, 2016, Overview of the Current Status and Development of Shale Gas and Shale Oil in Europe: Report T3b of the EUOGA Study (EU Unconventional Oil and Gas Assessment) Commissioned by JRCIET to GEUS, 133 p.

Becklumb, P., J. Chong, and T. Williamns, 2015, Shale Gas in Canada: Environmental Risks and Regulation: Economic: Resources and International Affairs Division, Publication No. 2015-18-E, 26 p.

Browning, J., S. Ikonnikova, G. Gülen, and S. Tinker, 2013, Barnett Shale Production Outlook: SPE Economics and Management, SPE-165585-PA, v. 5/3, 16 p. doi.org/10.2118/165585-PA

EC, 2014, Energy Economic Developments in Europe (EC 2014): European Commission, Brussels, Belgium, 160 p. doi:10.2765/72195

EIA, 2013, Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States: US Energy Information Administration (EIA), Washington, DC, 76 p. https://www.eia.gov/analysis/studies/worldshalegas/pdf/overview.pdf. Website accessed February 2019.

EIA, 2011, Review of Emerging Resources: U.S. Shale Gas and Shale Oil Plays: US Energy Information Administration (EIA), Washington DC, 105 p. https://www.eia.gov/analysis/studies/usshalegas/pdf/usshaleplays.pdf. Website accessed February 2019.

EIA, 2011, World Shale Gas Resources: An Initial Assessment of 14 Regions Outside the United States: US Energy Information Administration (EIA), Washington, DC, 365 p. https://www.eia.gov/analysis/studies/worldshalegas/archive/2011/pdf/fullreport.pdf. Website accessed February 2019.

Ter Heege, J., M. Zijp, S. Nelskamp, L. Doumaac, R. Verreussel, J. Ten Veen, G. Bruin, and R. Peters, 2015, Sweet Spot Identification in Underexplored Shales Using Multidisciplinary Reservoir Characterization and Key Performance Indicators: Example of the Posidonia Shale Formation in the Netherlands: Journal of Natural Gas Science and Engineering, v. 27/2, p. 558-577. doi.org/10.1016/j.jngse.2015.08.032

Zijp, M.H.A.A., S. Nelskamp, and J.C. Doornenbal, 2017, Resource Estimation of Shale Gas and Shale Oil in Europe: Report T7b of the EUOGA Study (EU Unconventional Oil and Gas Assessment) Commissioned by European Commission Joint Research Centre to GEUS, 34 p.

Website Cited

www.m4shalegas.eu Website accessed February 2019.

Advancing the World of Petroleum Geosciences.

EUROPEAN ASSOCIATION OF GEOSCIENTISTS & ENGINEERS

How sweet is European shale?

A story about the uncertain potential, problematic recovery and public concerns of shale gas development in Europe

Jan ter Heege

TNO Applied Geosciences, Utrecht, the Netherlands

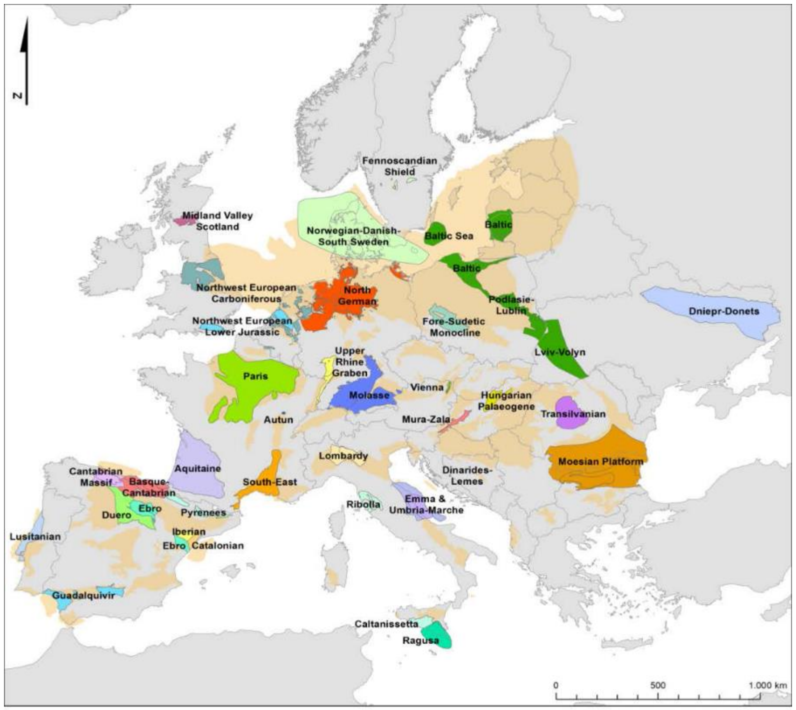
Data from European projects:

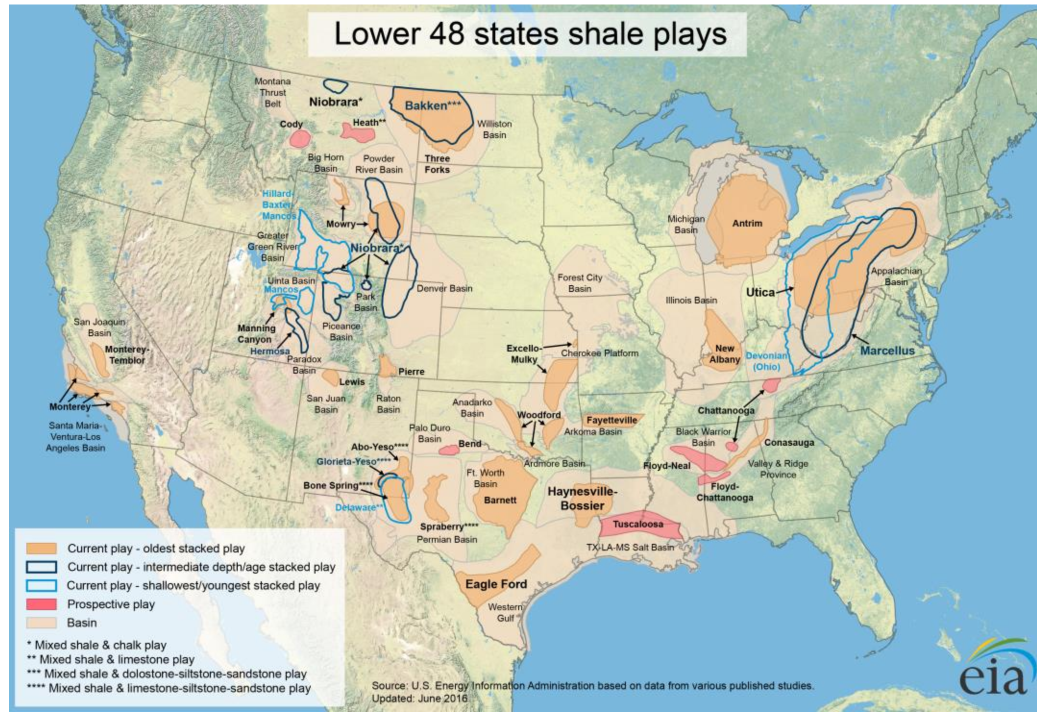
EUOGA: European Unconventional Oil and Gas Assessment

M4ShaleGas: Measuring, Monitoring, Mitigating & Measuring the environmental impact of shale gas

innovation for life

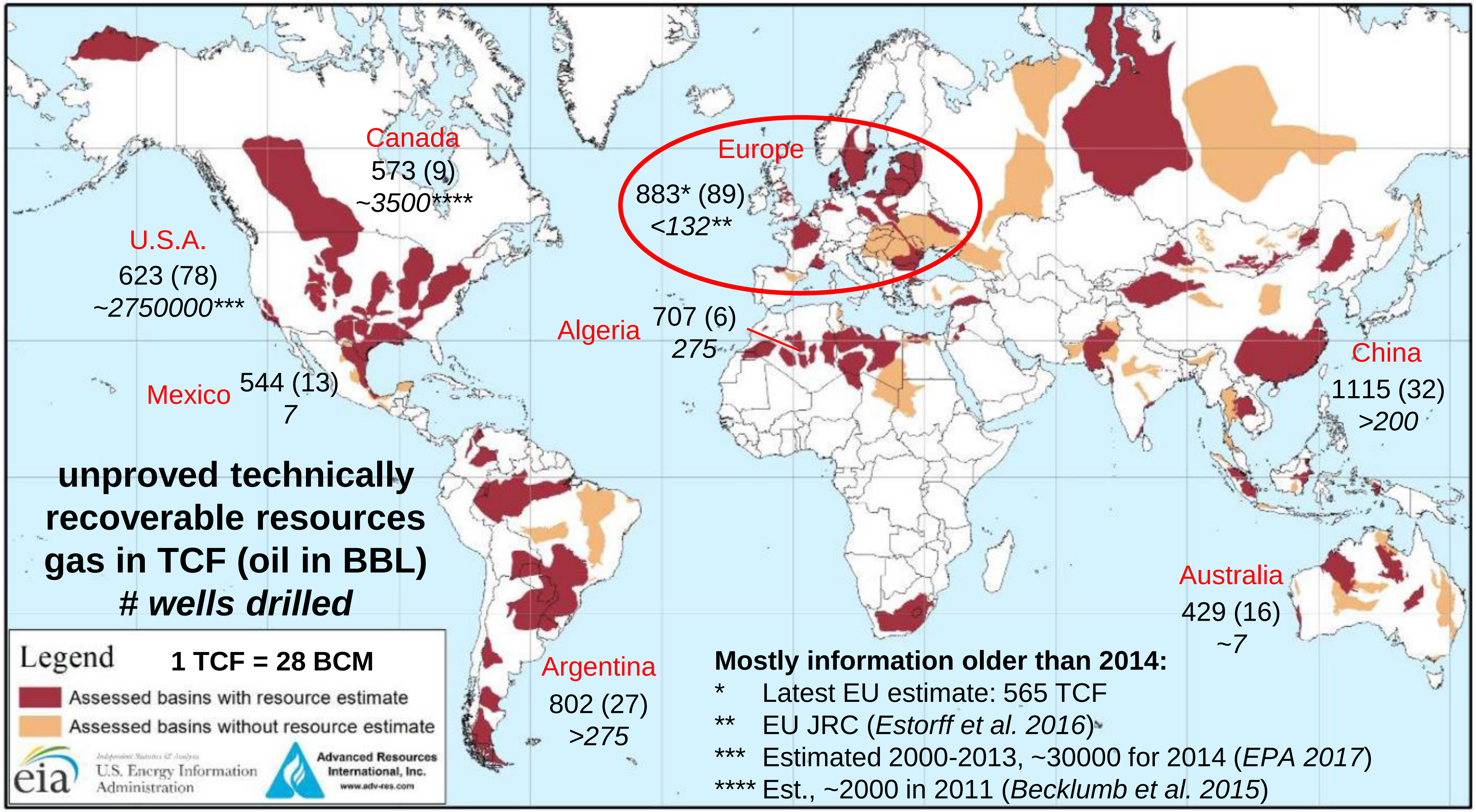
The European shale dilemma: Many shale basins but (very) limited activity





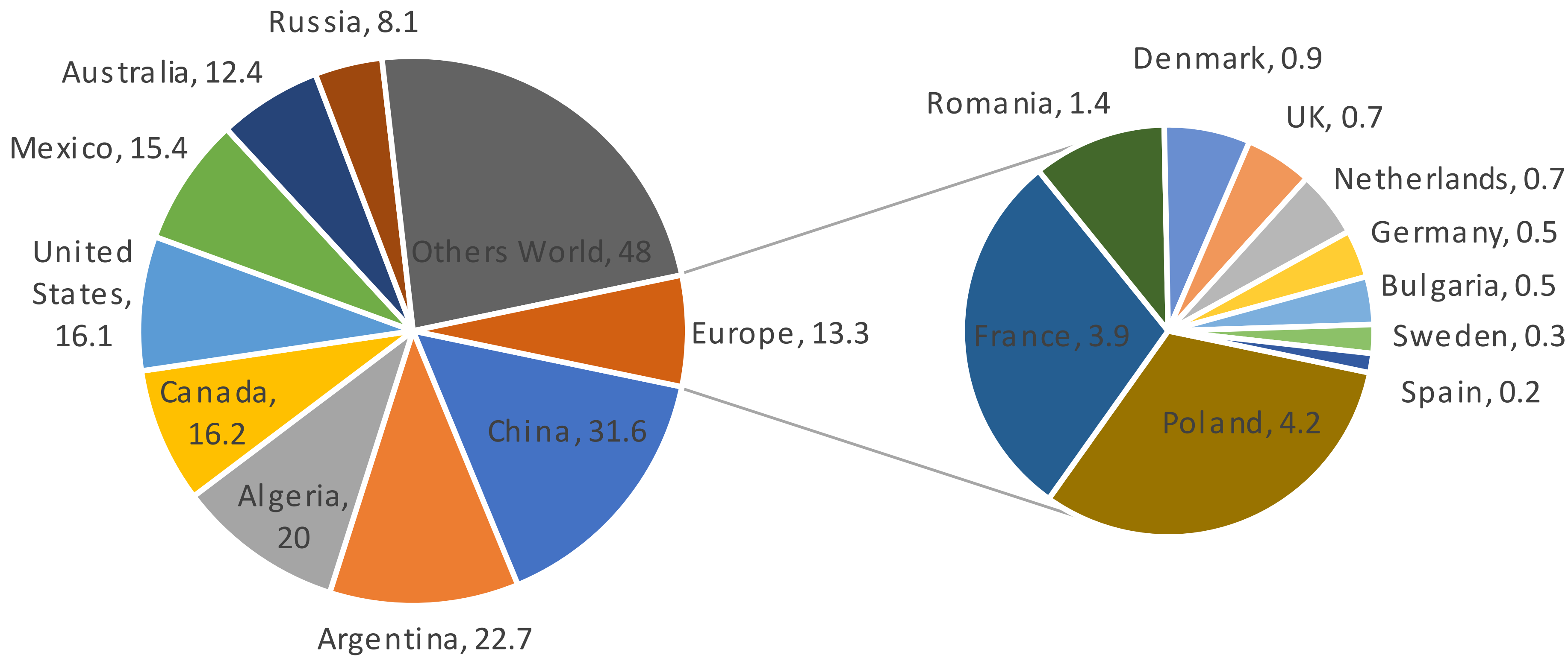
- Currently lack of success in Europe, but few hydraulically fractured horizontal wells
- Due to the lack of operations, comparison with North America is required to assess potential resources & recovery

Most wells drilled in North America, most resources located elsewhere?



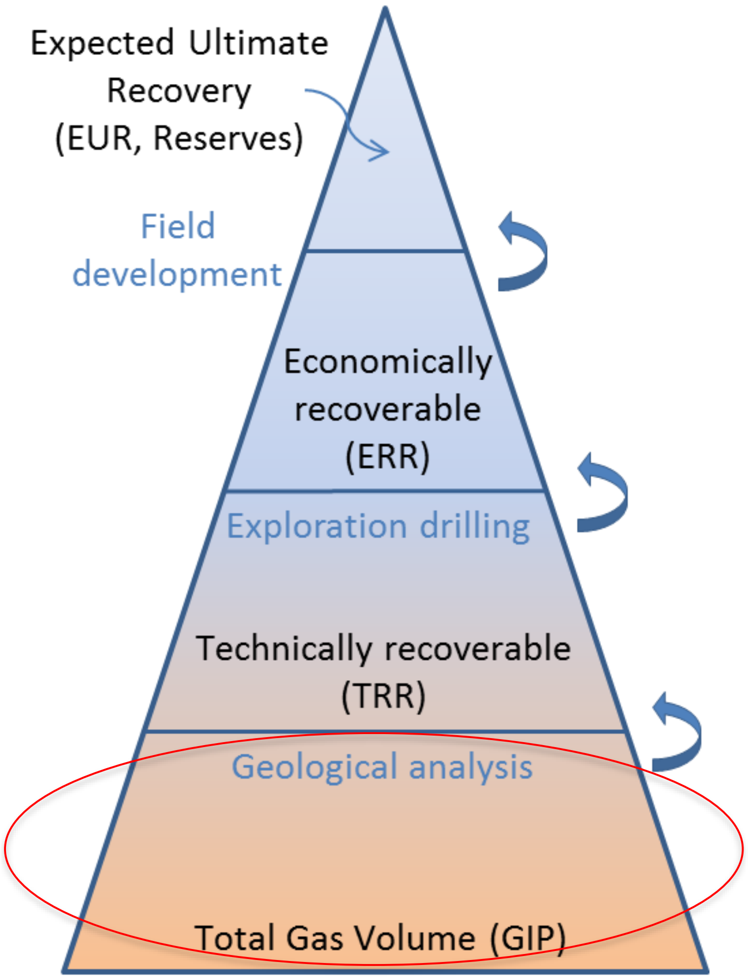
Assessment of technically recoverable resources outside U.S.A. very uncertain

Unproved Technically Recoverable Resources [1 TCM = 35.3 TCF]



Sources: Energy Economic Developments in Europe (EC 2014) based on analysis by the Energy Information Administration (EIA 2011, 2013)

European resource estimates subject to large uncertainties (restrict to GIIP)



- Determination of total GIIP:

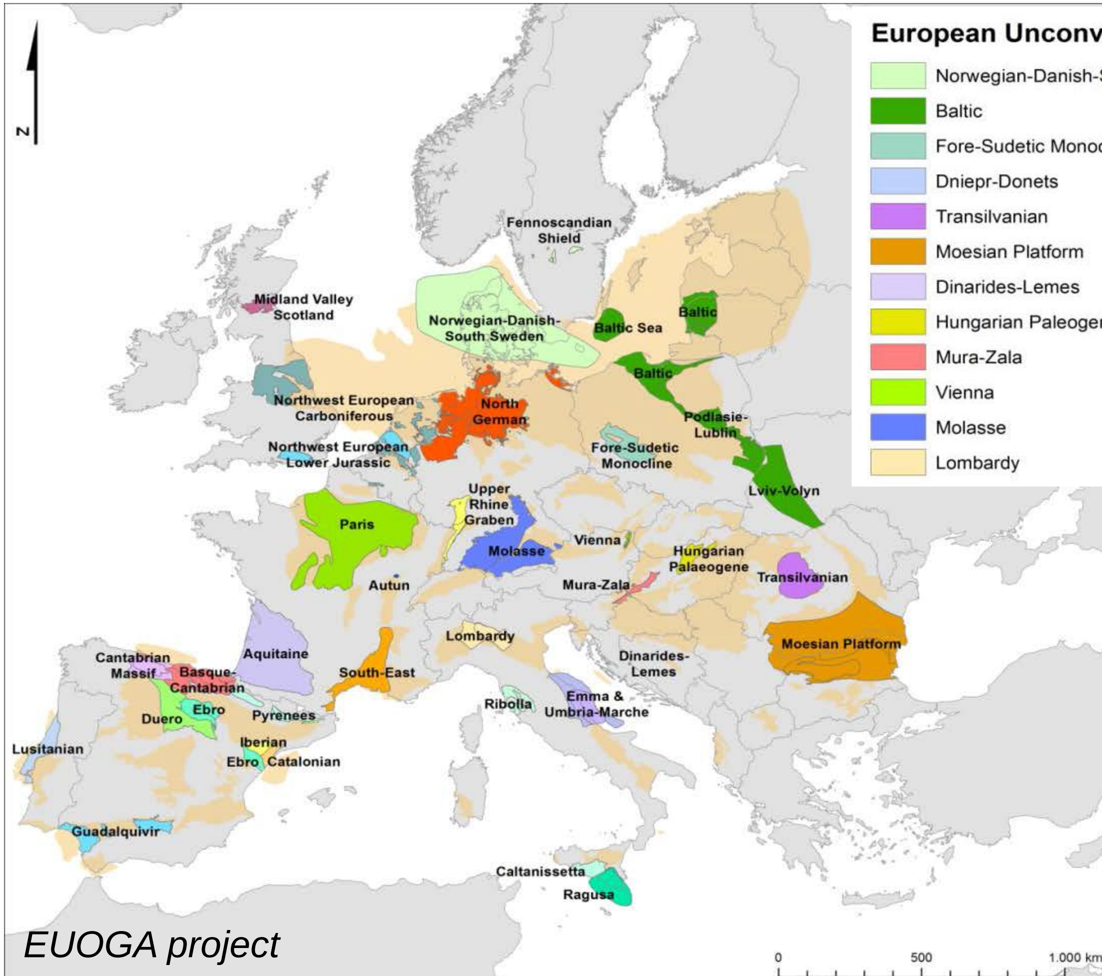
  $GIIP_{free} = A \times T \times \phi_{tot} \times S_{gas} \times F_e$ ("free" gas)

  $GIIP_{ads} = A \times T \times V_{ads}$ (adsorbed gas)

- Monte Carlo simulations using probability density functions for input parameters
- Recovery factor (R_f) from comparison with US ($TRR = GIIP_{tot} * R_f$)
- Limited available data for most plays

major sources of uncertainty (restrict to GIIP analysis)

Many sedimentary basins with shale formations present in Europe

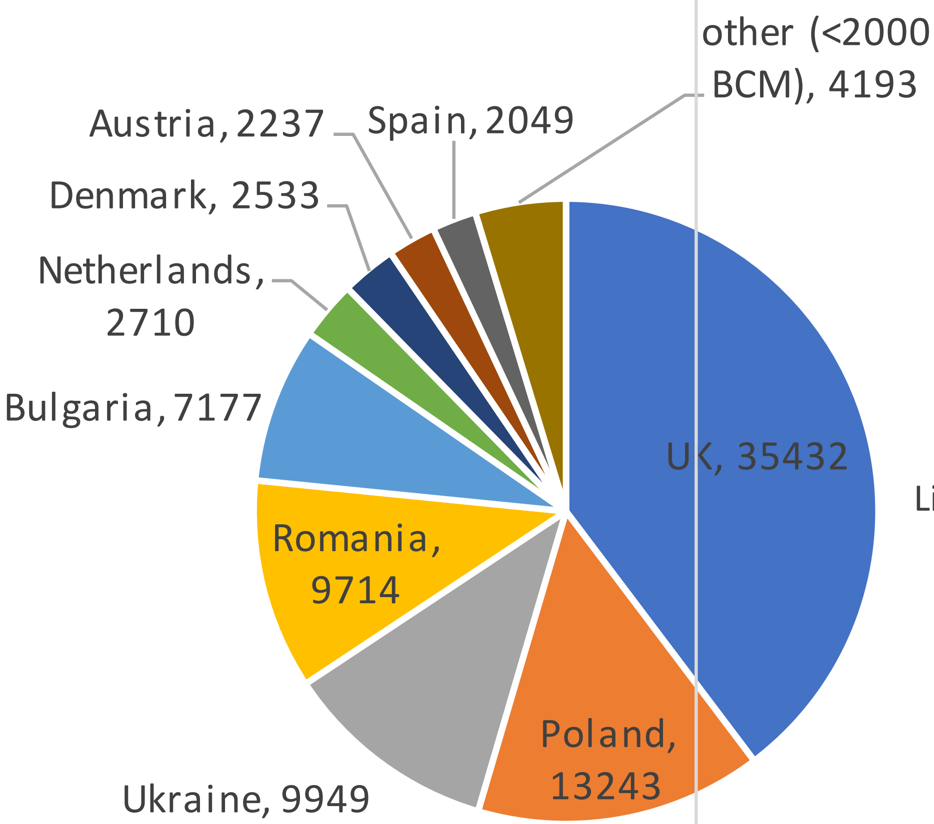


European Unconventional Oil and Gas Assessment (EUOGA):

- 21 countries (19 assessed)
- 38 shale basins
- 82 shale formations

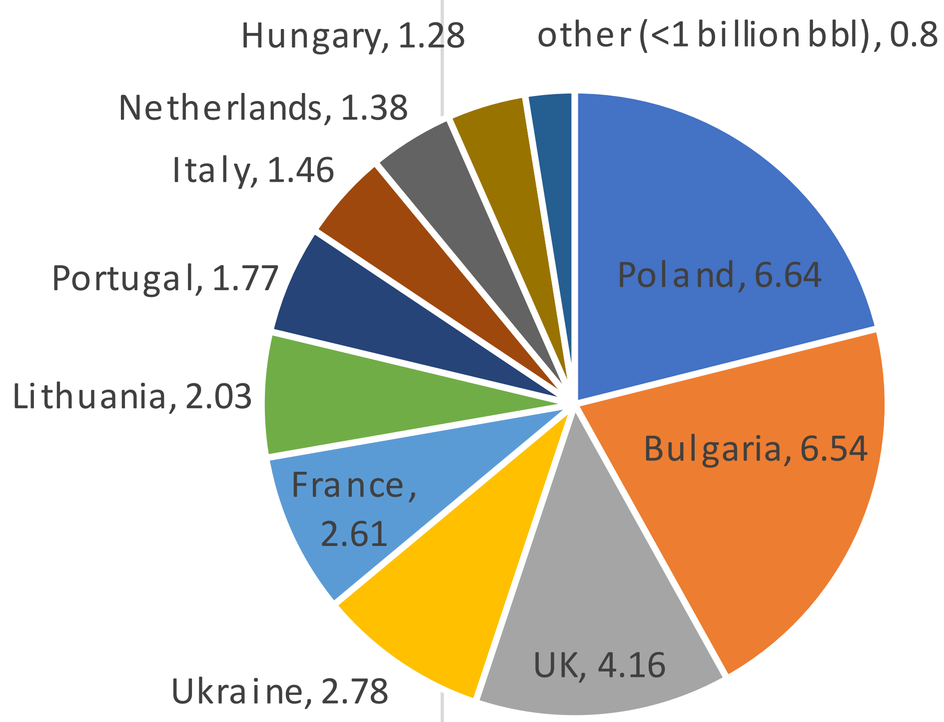
Significant resource estimates predicted for shale oil & gas in Europe

Total Europe: 89.2 TCM GIIP (P50)



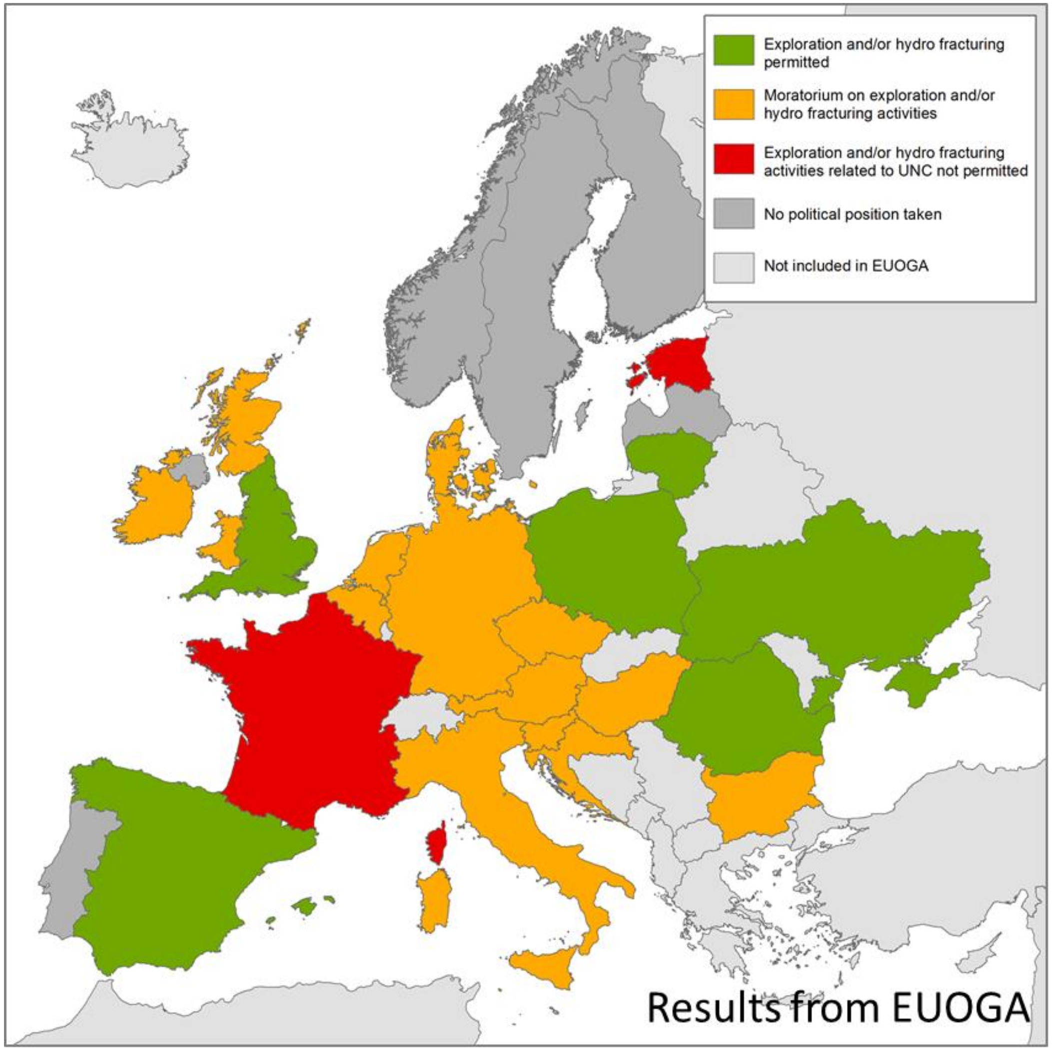
GIIP-gas P50 [BCM]

Total Europe: 31.4 billion bbl OIIP (P50)



GIIP-oil P50 [billion bbl]

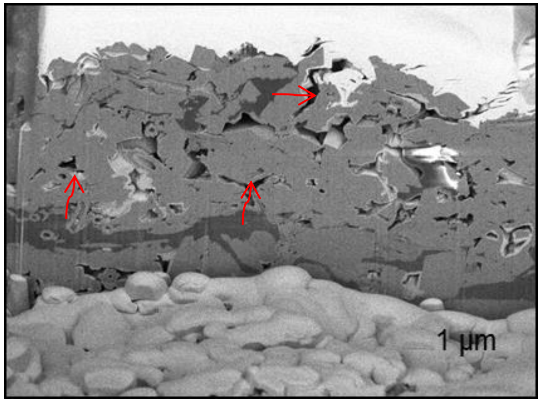
A problematic shale landscape in Europe



- **Technical issues:** Unsure shale resource & recovery due to lack of wells & production
- **Socio-political issues:**
    - Public concerns regarding groundwater and surface pollution due to fracking chemicals
    - Public concerns regarding climate footprints
    - Focus on renewable energy for a low carbon energy system
- **Energy security:** Domestic energy supply (import/export conventional gas)

Screening of shale potential and sweet spots using key performance indicators

Hydrocarbon generation

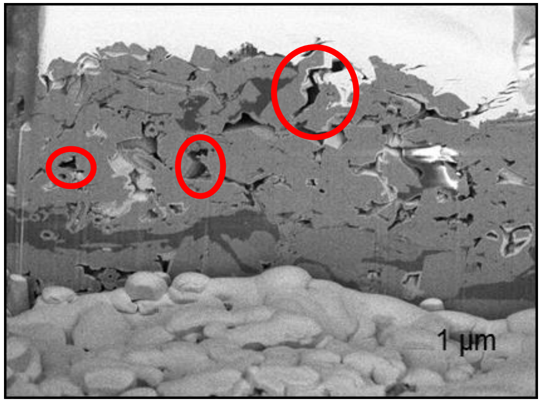


Performance indicator 1 (PI_g):

$$PI_g = \frac{R_0 - R_0^{min}}{R_0^{max} - R_0^{min}}$$

R_0 - Vitrinite reflectance

Hydrocarbon storage

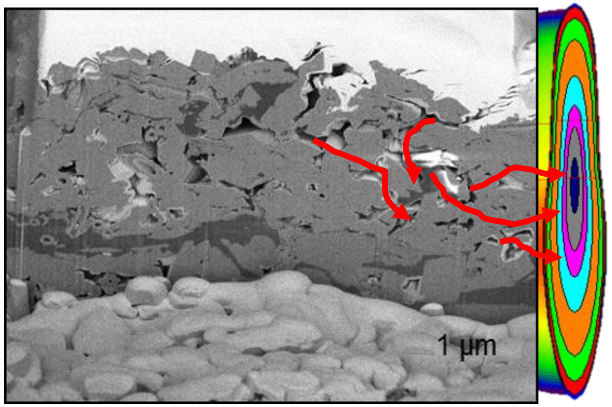


Performance indicator 2 (PI_s):

$$PI_s = \frac{SC_{tot} - SC_{tot}^{min}}{SC_{tot}^{max} - SC_{tot}^{min}}$$

SC – Storage capacity

Efficient flow stimulation



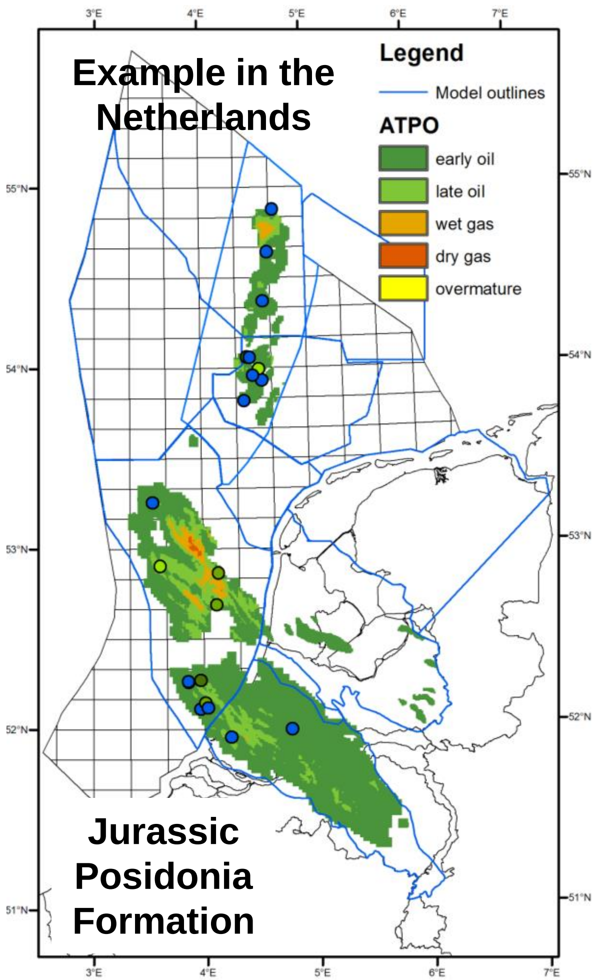
Performance indicator 3 (PI_f):

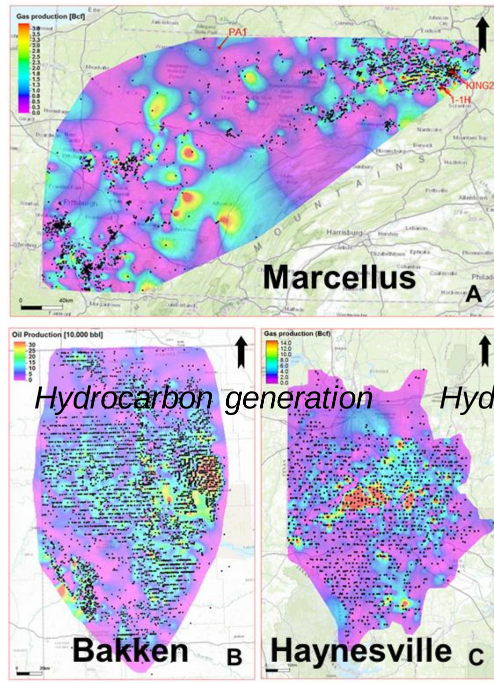
$$PI_f = \frac{1}{2}\left(\frac{BI_{min} - BI_{min}^{min}}{BI_{min}^{max} - BI_{min}^{min}} + \frac{BI_{dyn} - BI_{dyn}^{min}}{BI_{dyn}^{max} - BI_{dyn}^{min}}\right)$$

BI – Brittleness Index

Mean performance indicator (PI_{mean}): $PI_{mean} = \dfrac{3}{PI_g^{-1} + PI_s^{-1} + PI_f^{-1}}$ harmonic mean of 3 PI's

Performance indicators benchmarked against properties producing U.S. shales





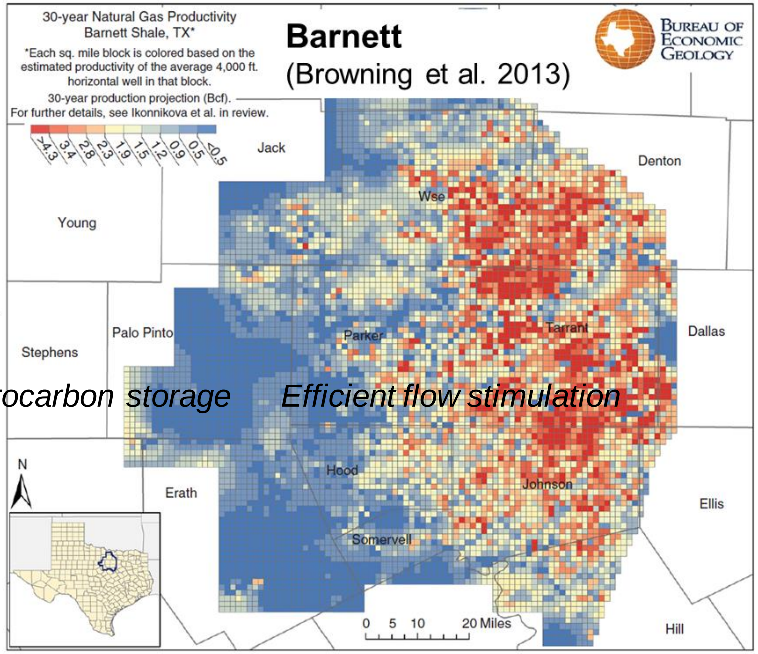


Fig. 3—30-year productivity map of 4,000-ft horizontal well.

Hydrocarbon generation | *Hydrocarbon storage* | *Efficient flow stimulation*

Performance indicator 1 (PI_g):

$$PI_g = \frac{R_0 - R_0^{min}}{R_0^{max} - R_0^{min}}$$

R_0 - Vitrinite reflectance

Performance indicator 2 (PI_s):

$$PI_s = \frac{SC_{tot} - SC_{tot}^{min}}{SC_{tot}^{max} - SC_{tot}^{min}}$$

SC – Storage capacity

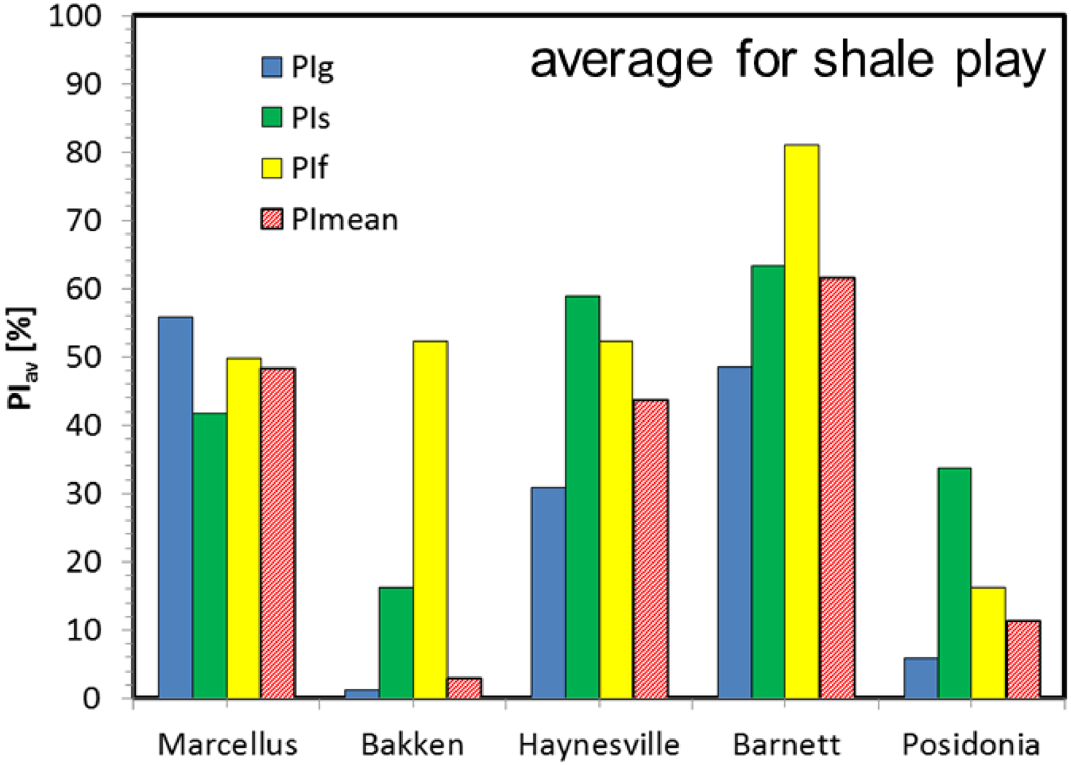
Performance indicator 3 (PI_f):

$$PI_f = \frac{1}{2}\left(\frac{BI_{min} - BI_{min}^{min}}{BI_{min}^{max} - BI_{min}^{min}} + \frac{BI_{dyn} - BI_{dyn}^{min}}{BI_{dyn}^{max} - BI_{dyn}^{min}}\right)$$

BI – Brittleness Index

Mean performance indicator (PI_{mean}): $PI_{mean} = \dfrac{3}{PI_g^{-1} + PI_s^{-1} + PI_f^{-1}}$ harmonic mean of 3 PI's

Performance indicators indicate limited potential for Posidonia Shale Formation

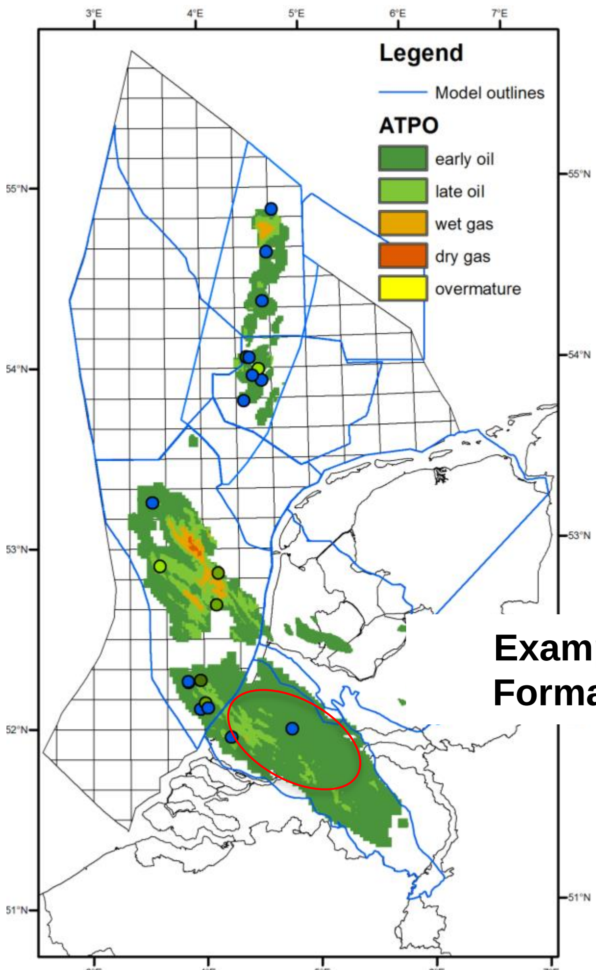


Performance indicators for the Jurassic Posidonia Formation in the Netherlands compared to some major producing U.S. shales (Ter Heege et al. 2015)

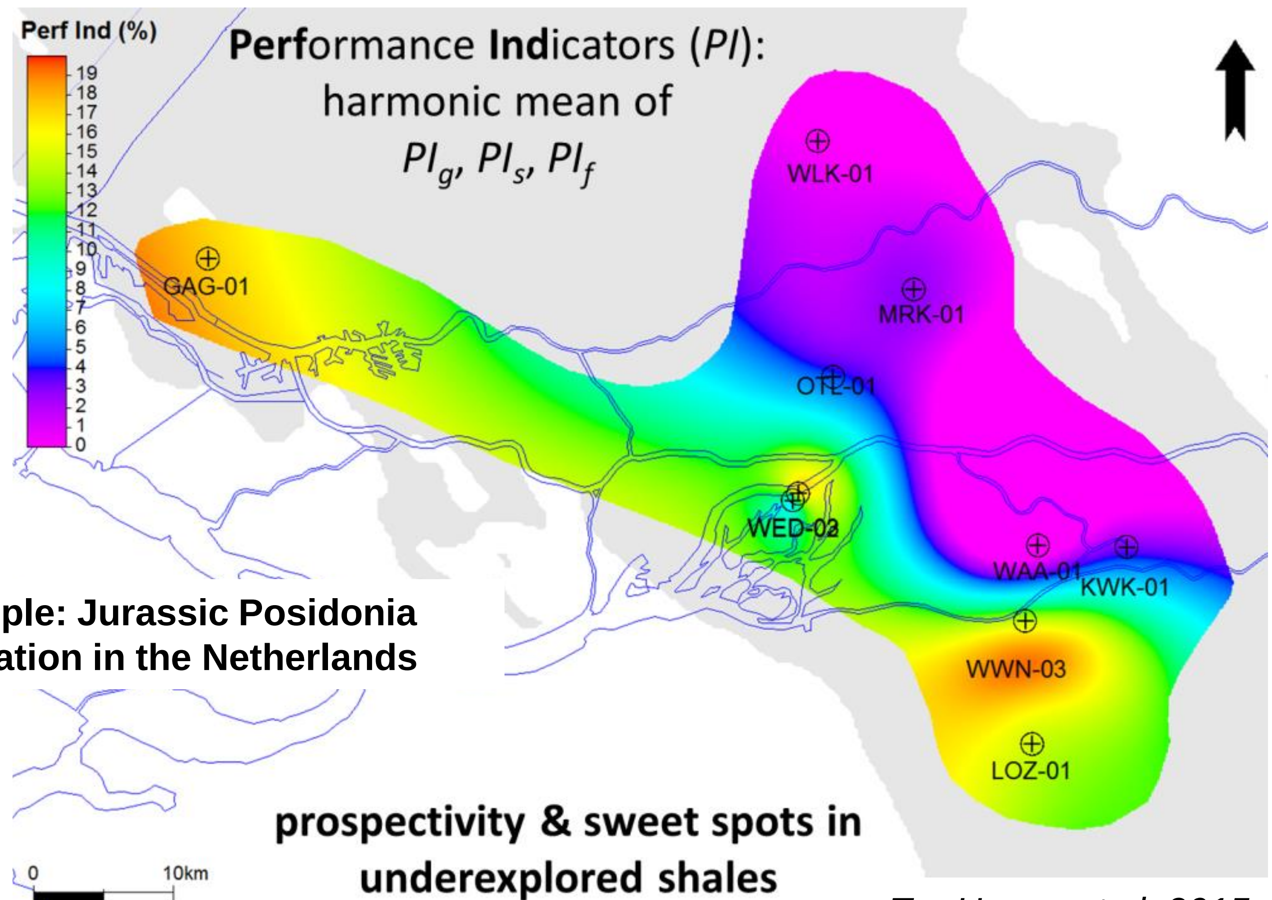
Posidonia Shale Formation:

- Limited potential for gas generation (oil to early gas maturity)
- Reasonable storage capacity for free and sorbed gas (available pore space)
- Poor potential for efficient flow stimulation (low brittleness: shale creep and proppant embedment)
- Limited overall potential (PI_{mean})

Mapping of "sweet" spots across shale formations with performance indicators



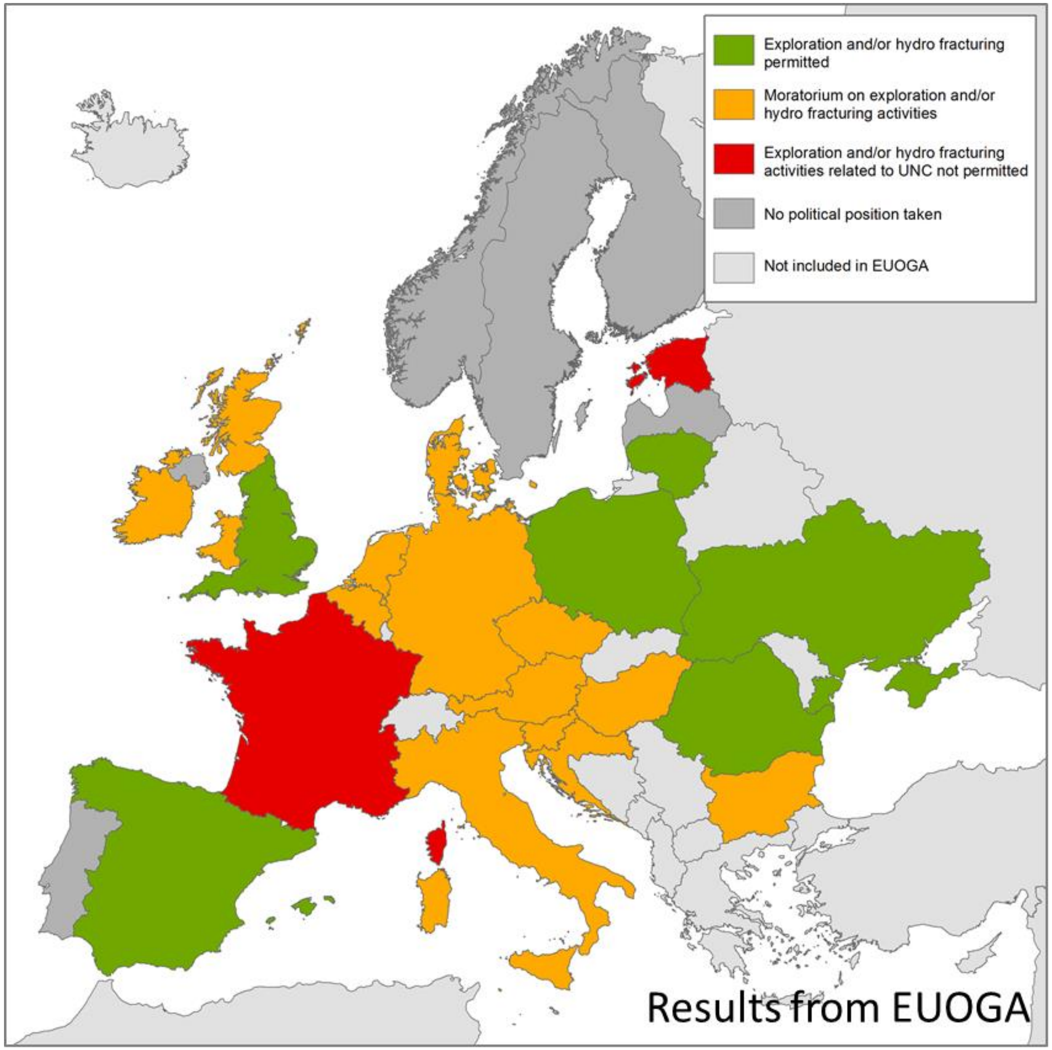
Example: Jurassic Posidonia Formation in the Netherlands



Ter Heege et al. 2015

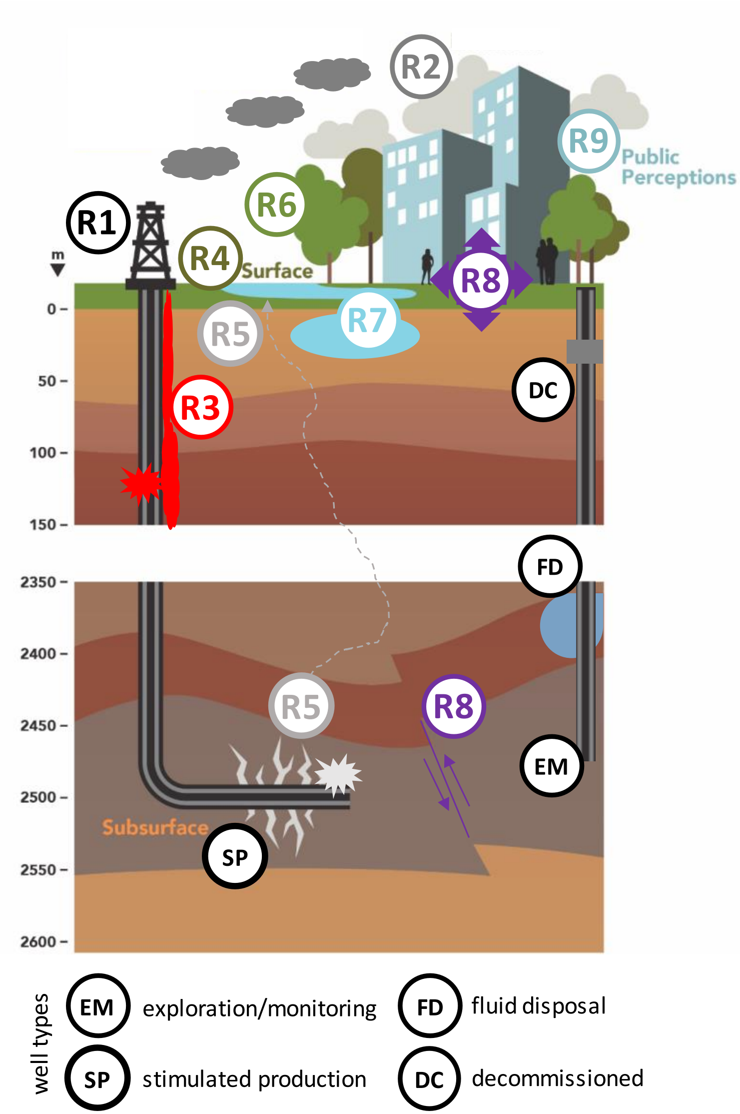
AAPG Advancing the World of Petroleum Geosciences. EAGE

A problematic shale landscape in Europe



- **Technical issues:** Unsure shale resource & recovery due to lack of wells & production
- **Socio-political issues:**
  - Public concerns regarding groundwater and surface pollution due to fracking chemicals
  - Public concerns regarding climate footprints
  - Focus on renewable energy for a low carbon energy system
- **Energy security:** Domestic energy supply (import/export conventional gas)

Shale operations & environmental impact



R1 *Reduced general safety:* Well site construction, storage & transportation

R2 *Reduced air quality & global climate footprint:* Emissions to air

R3 *Contamination due to well leakage:* Drilling, construction, completion, production or decommissioning of wells

R4 *Contamination due to surface spills & leaks:* Transportation, storage or handling of hazardous substances

R5 *Contamination due to loss of geological containment*: Out of zone fracturing & fluid migration

R6 *Landscape disturbance:* Local communities, wildlife, biotopes

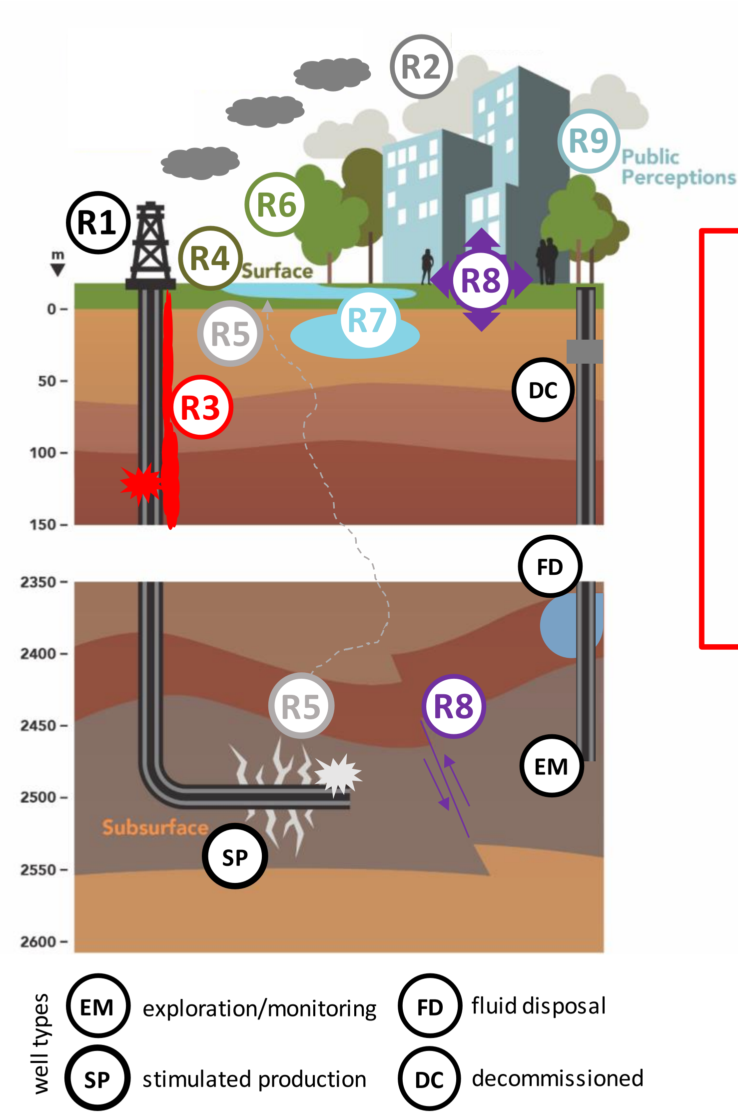
R7 *Reduced water availability & quality:* Extensive water use

R8 *Structural damage due to induced seismicity:* Hydraulic fracturing & waste water disposal

R9 *Lack of social license to operate:* Social, political & economic environment

M4ShaleGas
Measuring, Monitoring, Mitigating, Managing the Environmental Impact of Shale Gas
www.m4shalegas.eu

Shale operations & environmental impact



R1 *Reduced general safety:* Well site construction, storage & transportation

R2 *Reduced air quality & global climate footprint:* Emissions to air

R3 *Contamination due to well leakage:* Drilling, construction, completion, production or decommissioning of wells

R4 *Contamination due to surface spills & leaks:* Transportation, storage or handling of hazardous substances

R5 *Contamination due to loss of geological containment*: Out of zone fracturing & fluid migration

R6 *Landscape disturbance:* Local communities, wildlife, biotopes

R7 *Reduced water availability & quality:* Extensive water use

R8 *Structural damage due to induced seismicity:* Hydraulic fracturing & waste water disposal

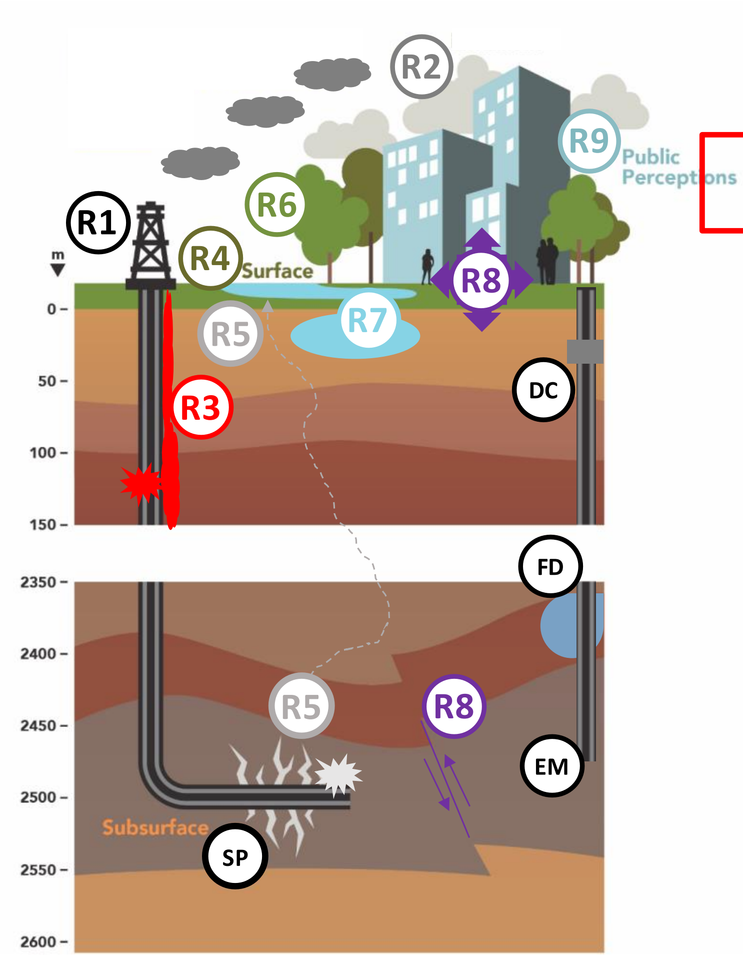
R9 *Lack of social license to operate:* Social, political & economic environment

Poor well construction more important than leakage along hydraulic fractures

M4ShaleGas
Measuring, Monitoring, Mitigating, Managing the Environmental Impact of Shale Gas
www.m4shalegas.eu

AAPG Advancing the World of Petroleum Geosciences
EAGE

Shale operations & environmental impact



well types

- **EM** exploration/monitoring
- **FD** fluid disposal
- **SP** stimulated production
- **DC** decommissioned

R1 *Reduced general safety:* Well site construction, storage & transportation

R2 *Reduced air quality & global climate footprint:* Emissions to air

R3 *Contamination due to well leakage:* Drilling, construction, completion, production or decommissioning of wells

R4 *Contamination due to surface spills & leaks:* Transportation, storage or handling of hazardous substances

R5 *Contamination due to loss of geological containment*: Out of zone fracturing & fluid migration

R6 *Landscape disturbance:* Local communities, wildlife, biotopes

R7 *Reduced water availability & quality:* Extensive water use

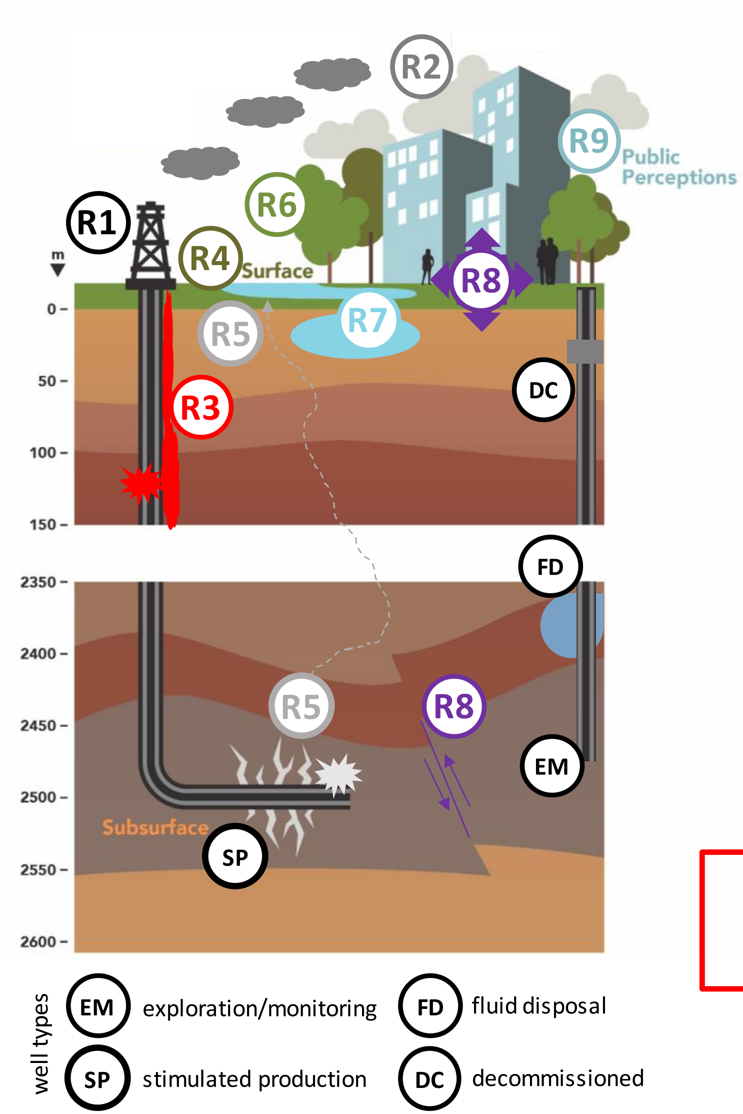
R8 *Structural damage due to induced seismicity:* Hydraulic fracturing & waste water disposal

R9 *Lack of social license to operate:* Social, political & economic environment

Methane leakage can increase climate footprint of shale gas to that of coal if not properly mitigated

M4ShaleGas
Measuring, Monitoring, Mitigating, Managing the Environmental Impact of Shale Gas
www.m4shalegas.eu

Shale operations & environmental impact



R1 *Reduced general safety:* Well site construction, storage & transportation

R2 *Reduced air quality & global climate footprint:* Emissions to air

R3 *Contamination due to well leakage:* Drilling, construction, completion, production or decommissioning of wells

R4 *Contamination due to surface spills & leaks:* Transportation, storage or handling of hazardous substances

R5 *Contamination due to loss of geological containment:* Out of zone fracturing & fluid migration

R6 *Landscape disturbance:* Local communities, wildlife, biotopes

R7 *Reduced water availability & quality:* Extensive water use

R8 *Structural damage due to induced seismicity:* Hydraulic fracturing & waste water disposal

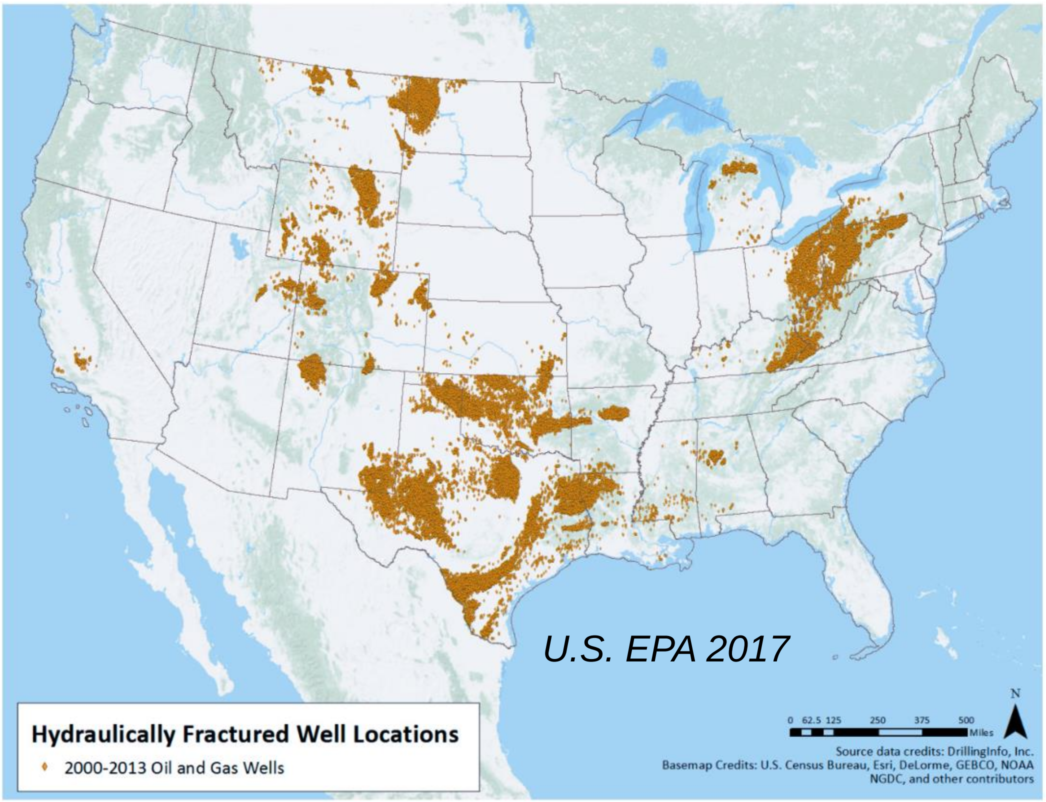
R9 *Lack of social license to operate:* Social, political & economic environment

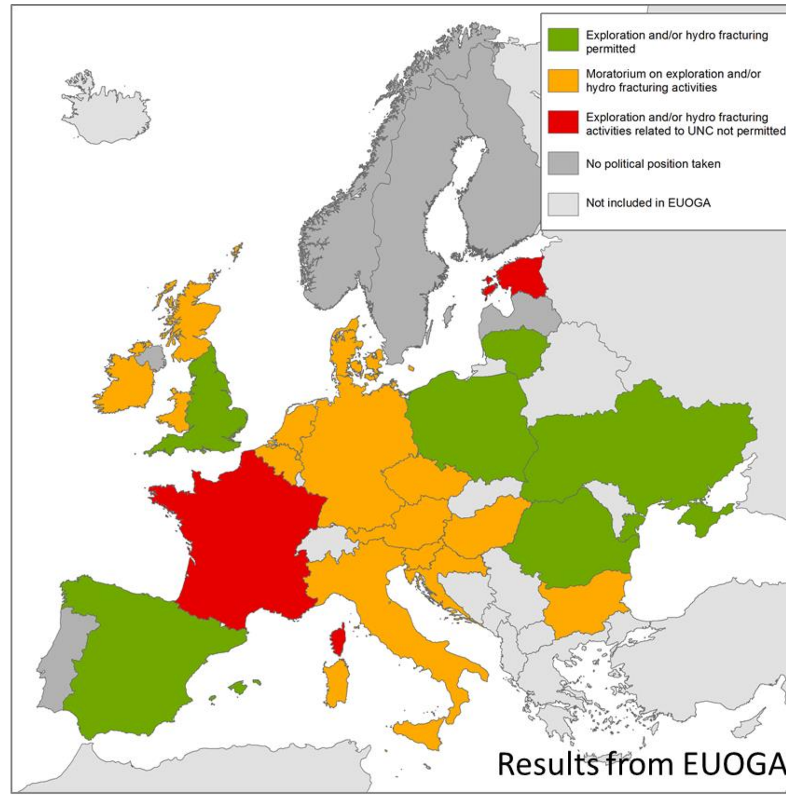
M4ShaleGas
Measuring, Monitoring, Mitigating, Managing the Environmental Impact of Shale Gas
www.m4shalegas.eu

Damaging induced seismicity for waste water disposal (e.g., Oklahoma), some related to hydraulic fracturing (W. Canada)

AAPG
Advancing the World of Petroleum Geosciences
EAGE

Comparisons are valuable but North America is not a blueprint for Europe





U.S.A.: Estimated 275000 wells drilled and hydraulically fractured in 2000-2013 (~30000/year in recent years)
Europe: Limited activity, most countries have moratorium on shale exploration and/or hydraulic fracturing

Different scale of operations compared to North America or conventional gas

Marcellus well site with 50 multi-stage hydraulic fractured horizontal wells (Oct 2016)

Well site at Weeton with Preese Hall hydraulically fractured (2011) vertical well targeting the Bowland Shale in Lancashire, England (abandoned & site restored, 2015)

Conclusions:

- **Significant shale resources in Europe**, but potential for **recovery is uncertain** due to limited data & operations
- Currently, shale gas operations in Europe are mainly limited due to **public concerns about hydraulic fracturing and climate footprint**
- Main differences in environmental impacts between **conventional & unconventional gas** exploitation are due to **scale of operations**