Centre de Mathématiques Appliquées

Chaire ParisTech Modélisation prospective
au service du développement durable

Quand les gaz de roche mère bouleversent la donne: impacts économiques sur le gaz européen.

Yoann Desgrange et Xavier Dran

Summary

- State of the art:
  - What is unconventional gas?
  - History of the shale gas development
  - Global reserve estimations
- Development of shale gas in Europe:
  - Challenges
  - Opportunities
  - Case studies
- Europe gas supply:
  - Demand and current import streams
  - Impact of the development of shale gas in the rest of the world
  - Consequences on the evolution of the supply mix

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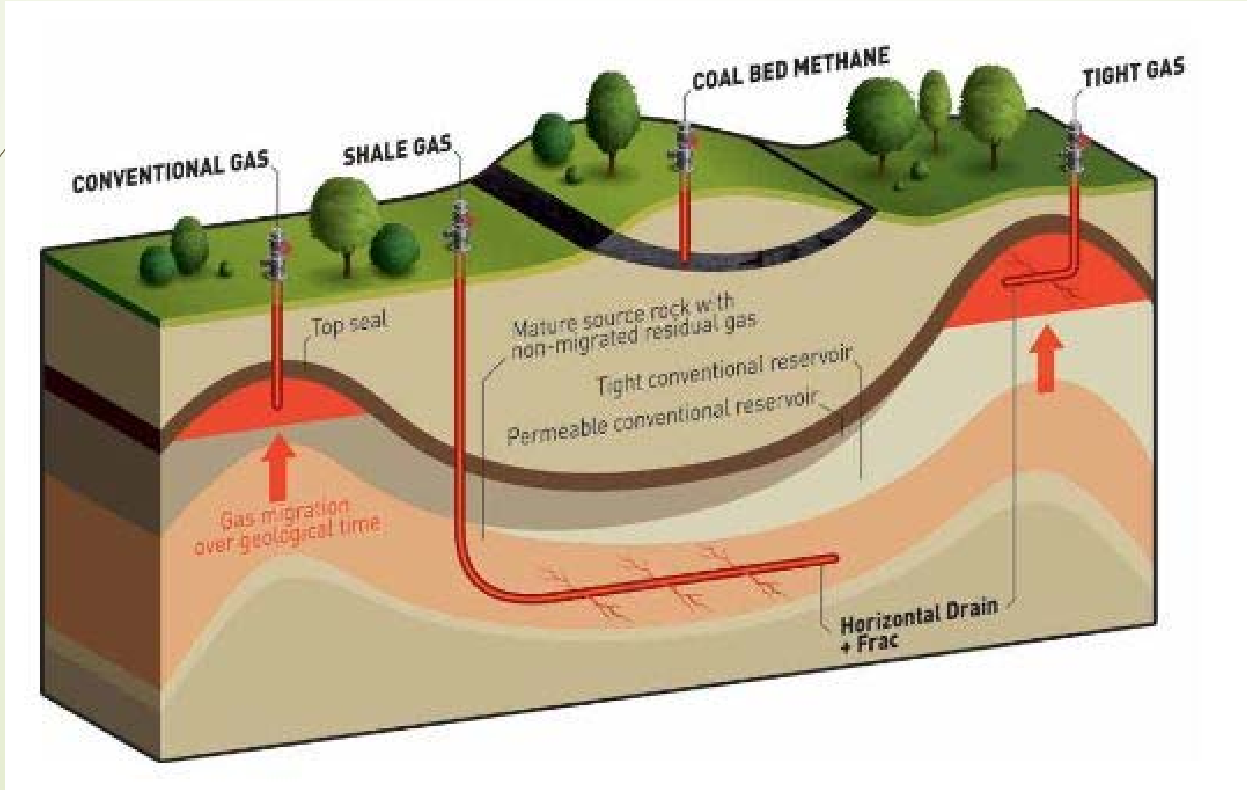
State of the art

- What is unconventional gas?
- History of shale gas development
- Global reserve estimations

What is unconventional gas?

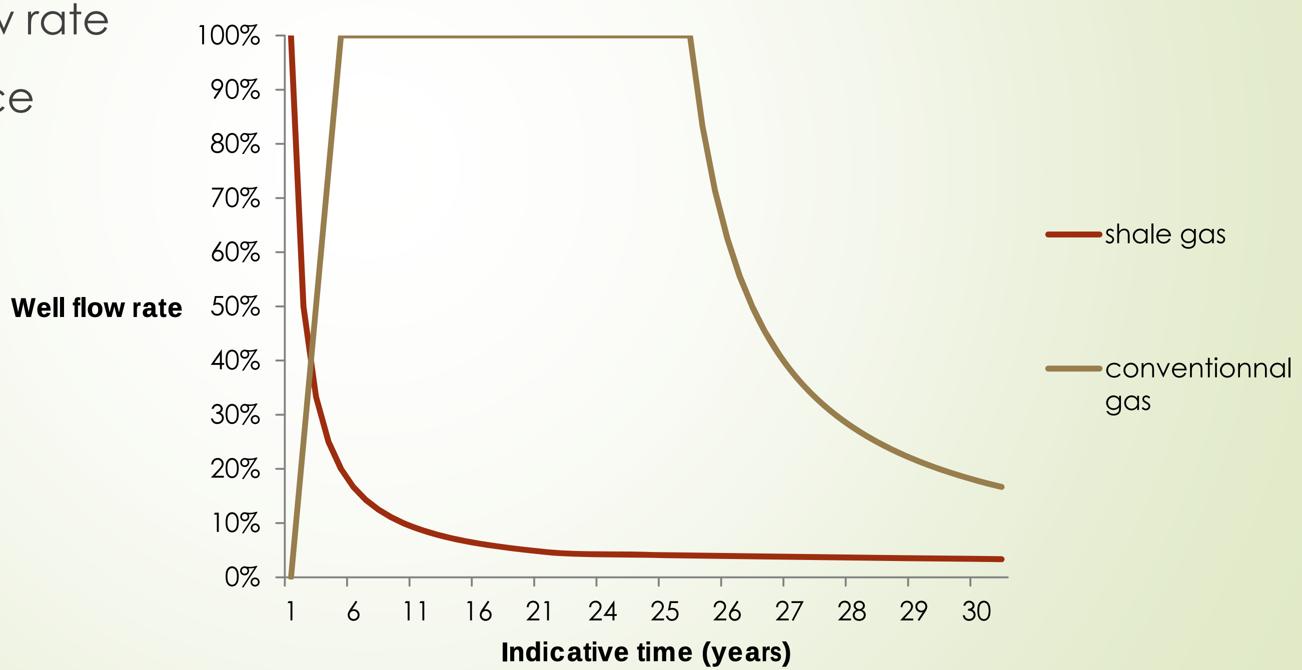
- Different types of unconventional gas:



Source: Total 2014

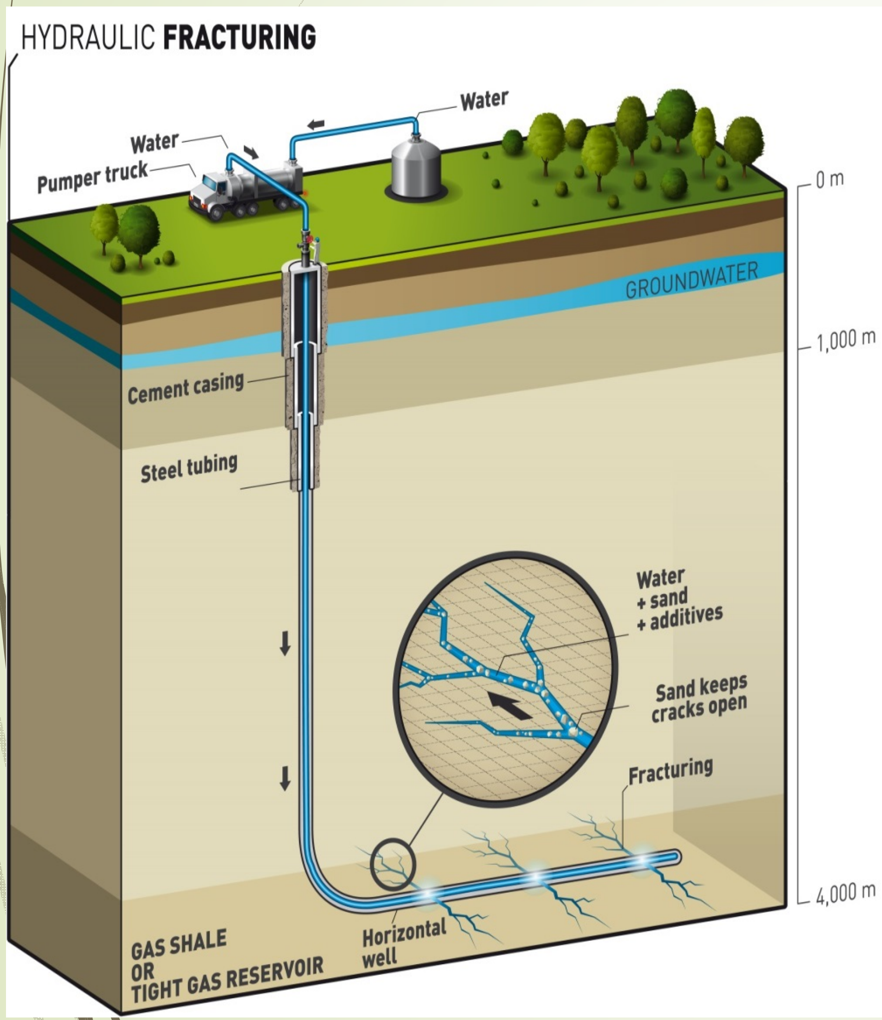
What is unconventional gas?

- Main differences with conventional gas:
  - Underground fracking and horizontal drilling
  - Well lifetime
  - Well flow rate
  - Well price



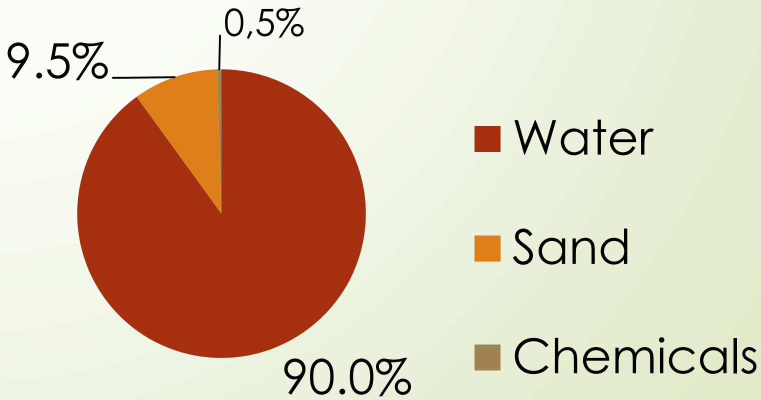
Typical production rate of gas wells over time

Exploitation



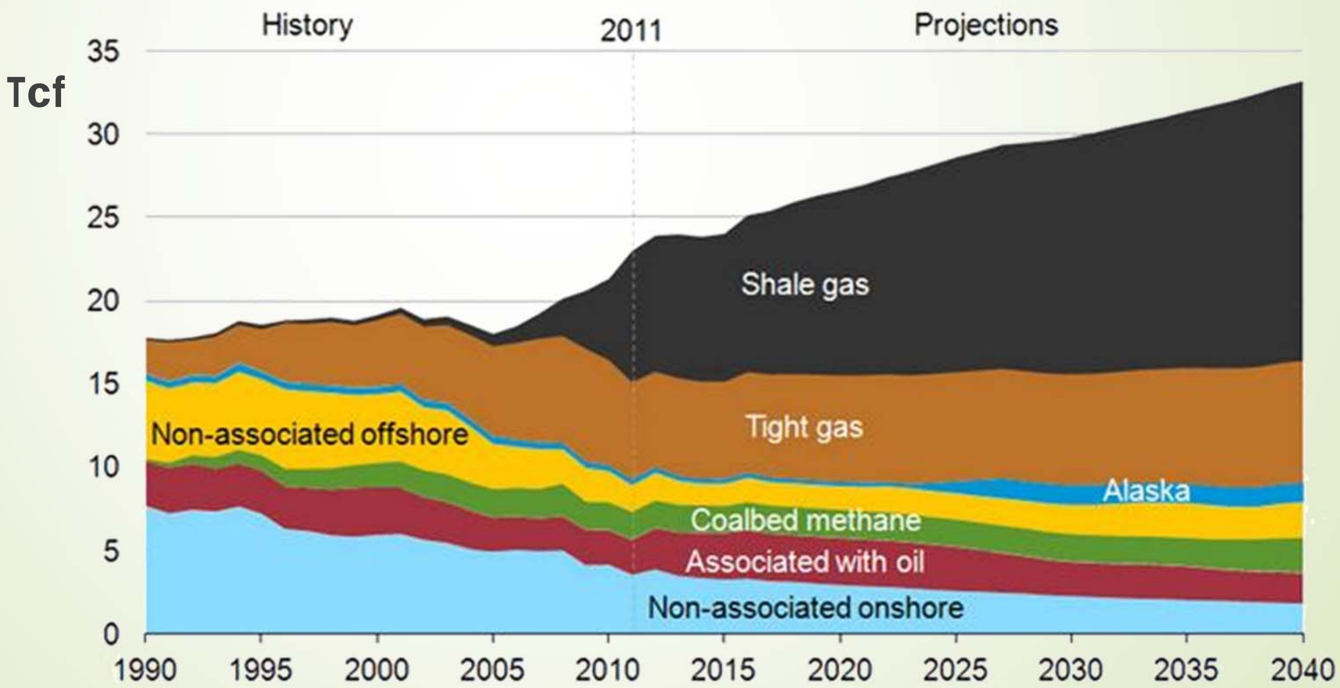
- Well construction
  - (Vertical and horizontal drilling)
- Perforations in the production casing
- Hydraulic Fracturing (around 15,000 m^3 of water)

Volumetric composition of a fracture fluid



History of shale gas development

- 1821: the first natural gas exploitation was shale gas, in the New York Province
- Shale gas: 1.6% of total US natural gas production in 2000, 23.1% by 2010 and around 50% expected in 2040

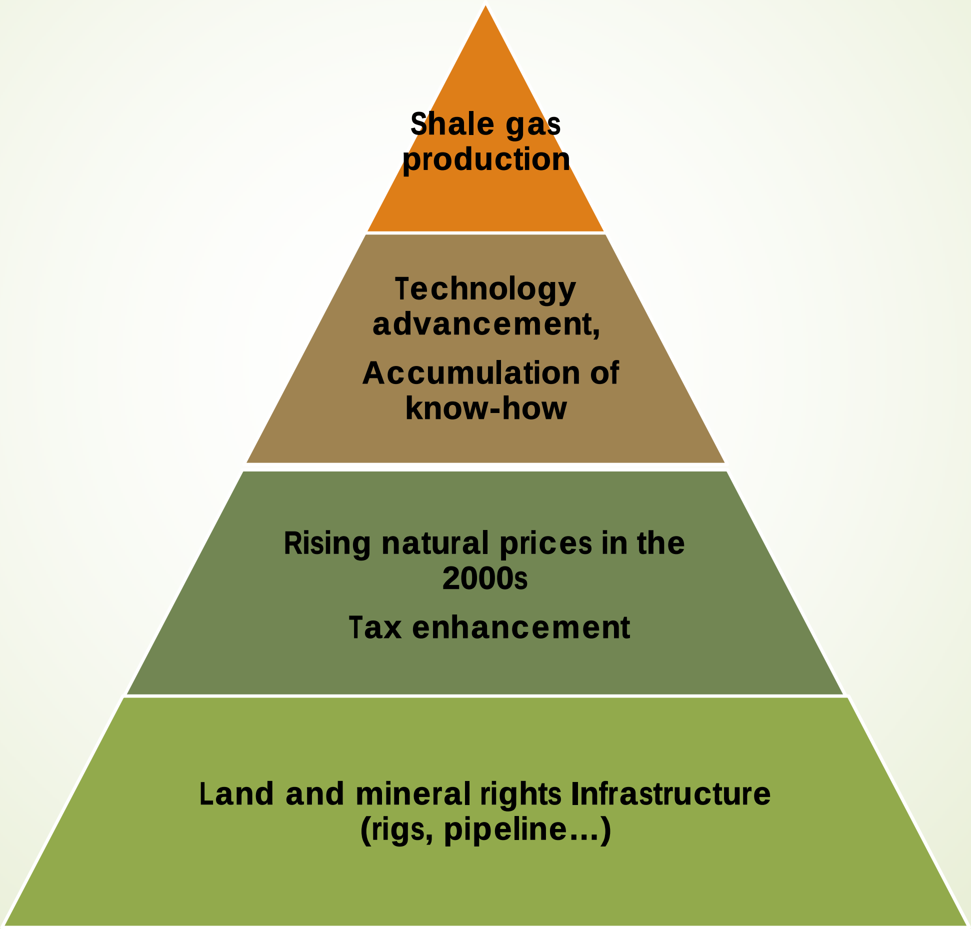


Annual US Natural gas production and projected production by gas type 1990-2040 in Tcf

Source: EIA 2013

History of shale gas development

- What led to the shale gas boom in the United States?

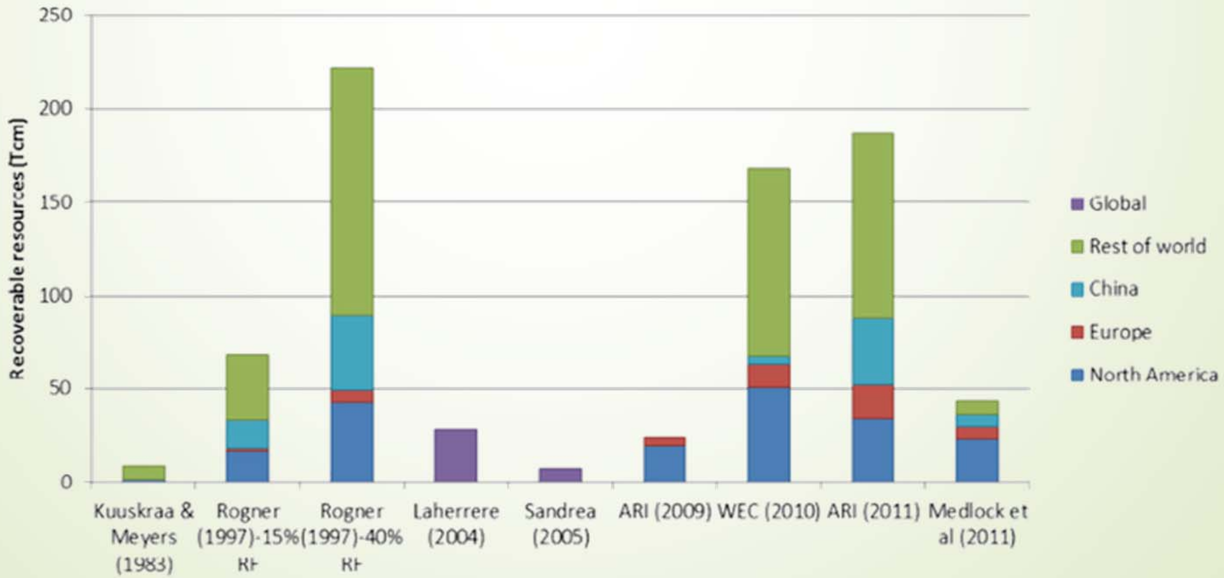


A Retrospective Review of Shale Gas Development in the US

Source: Z.Wang and A.Krupnick, 2013

Resources and reserves

- EIA: a single data source…
- Large uncertainties inside North America (EIA/ARI)
- Large uncertainties outside North America
  - Lack of exploration, especially in Europe
- Proved/Probable reserves: gas recovery factor: 20 to 40%



Unconventional gas reserves estimates

Source: European Commission, 2012

Development of shale gas in Europe

- Challenges
- Opportunities
- Case studies

Challenges

- Mining law
  - In the US: ownership of the land induces ownership of the underground resources
    - Usually, 12-20% of the earnings go to the landowner
    - Strong incentive for the owners
  - In European countries: resources belong to the state
    - Need for state approval
    - Exploration seen as the threat by the owner

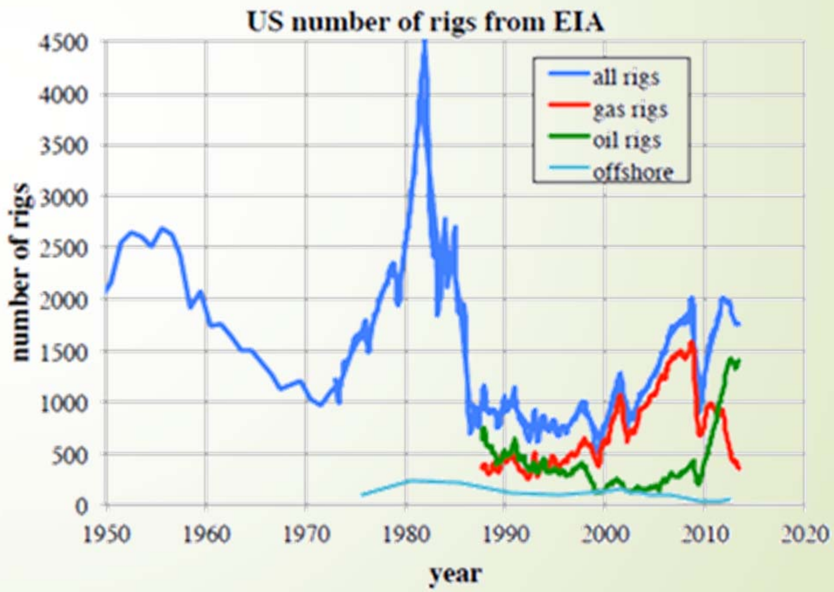
- Higher density
  - Higher land costs
  - Industrial externalities become sensitive issues

    (noise, truck traffic)

Challenges

- Drilling industry:
  - Rig: drilling device
  - Constant drilling needs
  - US: mature technology, large number of rigs
  - EU: no rig, no industrial network
- Pipeline network
- Water prices

	Total rigs	Gas rigs	Land rigs	Horizontal rigs
US	1,808	421	395	292
Europe	120	24	18	13



Sources: Hughes, 2012 – Laherrere, 2013

Challenges

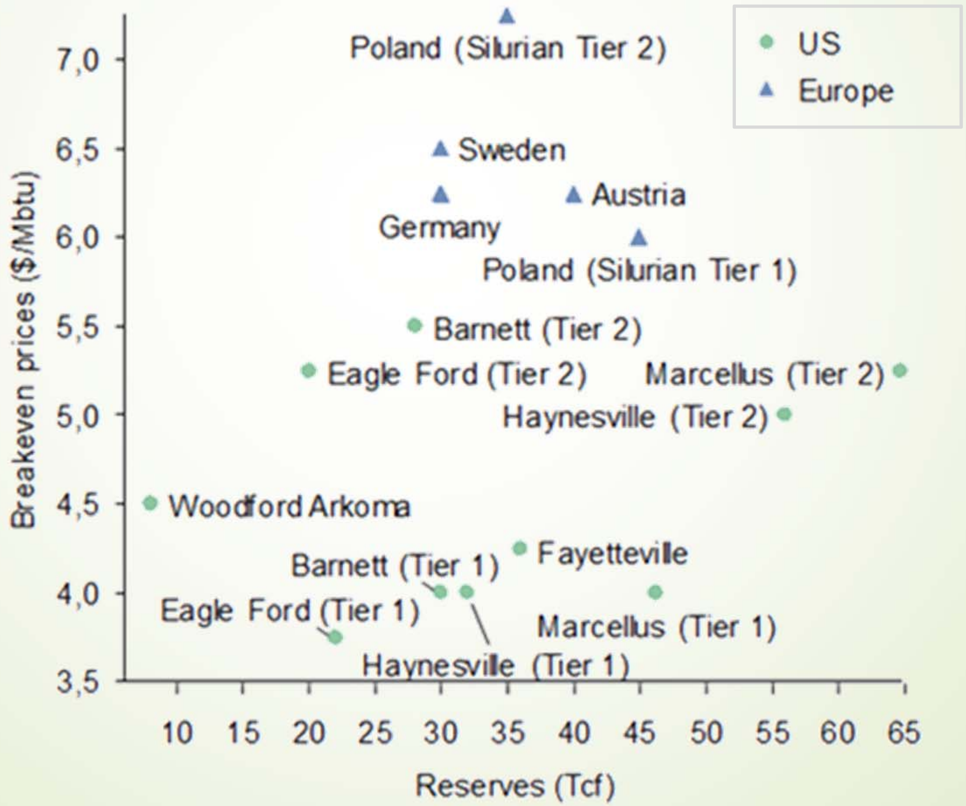
- Environmental concerns

- The following risks are noteworthy:
  - Water management in the fracking process
  - Potential seismic risks
  - Inconveniences to the public (constant drilling activity in populated areas)
  - Greenhouse gas and chemicals

- Local resistance
  - Fracking outlawed in several countries (France…)

Opportunities

- Alleged important potential in some European countries:



Shale gas reserves and costs

Source: Medlock, Myers Jaffe and Hartley, *2011*

Opportunities

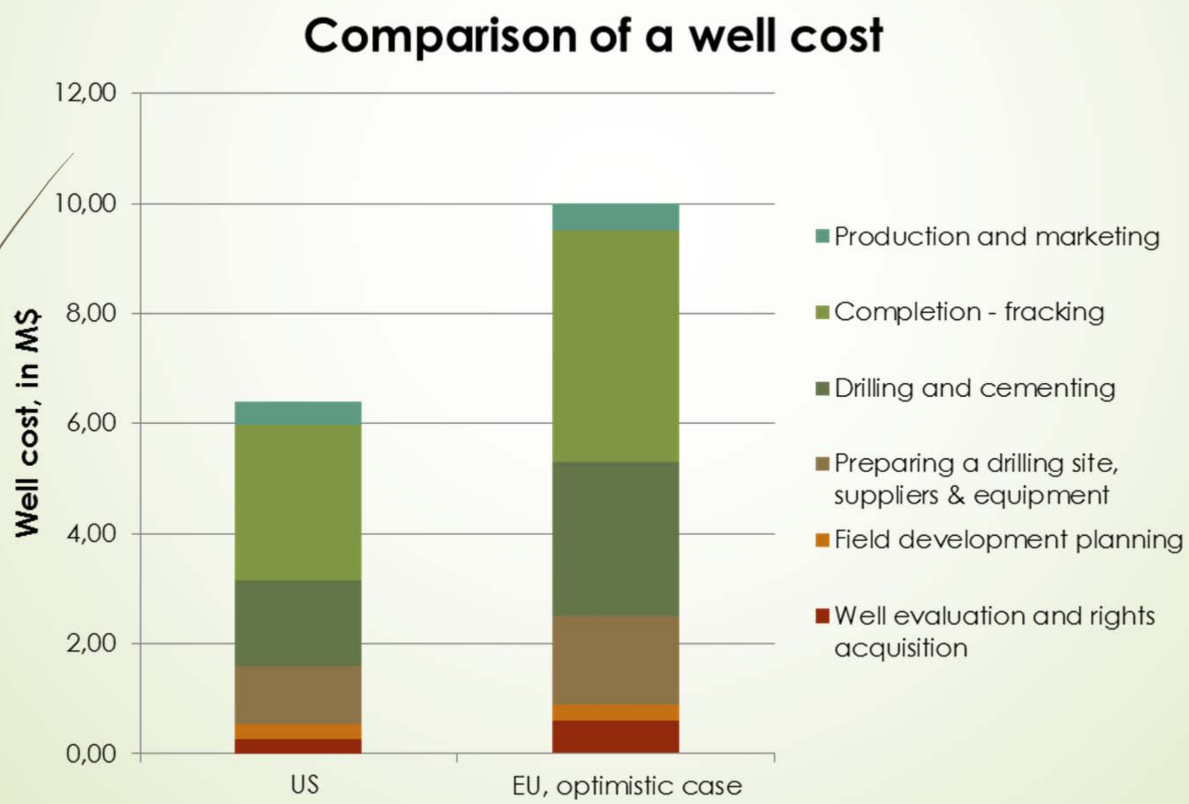
- Political reasons: independence from oil-exporting countries

- Competitiveness issue for the European industry
  - Energy-intensive industries moving away (to the US…)
  - Securing energy supply
  - Recurring activities in unconventional gas prospection, exploration and production

- Improvement of the trade balance

Consequences

- Higher well price expected in Europe
  - At least 10 M$, vs 5-6 M$ in the US

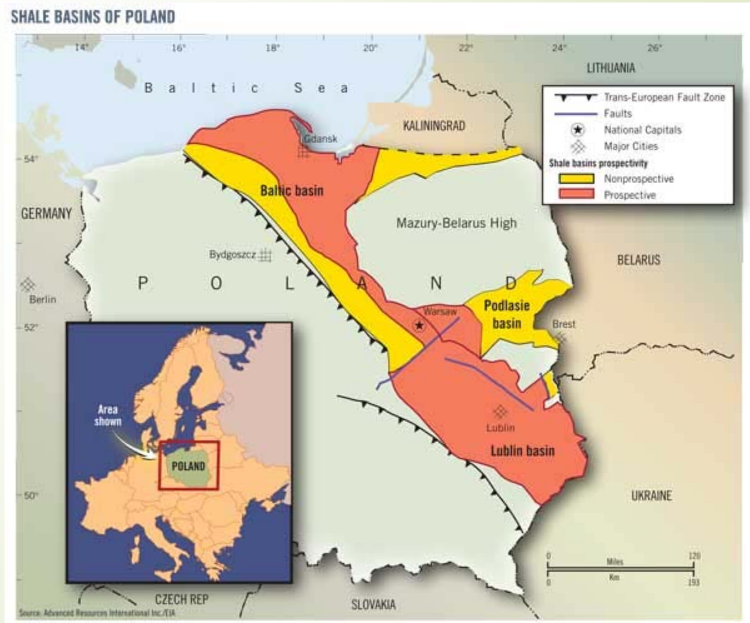


Source : Boston Consulting Group, 2010 - INSEAD, 2013

Case studies - Poland

- European pioneer
- Strong political support
- 2011 reserves assumption: 5.3 Tm^3
  - Lublin, Baltic and Danish-Polish basins
  - 2012: divided by 10
  - Likely to be increased again
- Exxon Mobil exited
- Drilling price in Poland: 11M$/well (Schlumberger)

Shale gas reserves in Poland



Source: Polish shale gas, 2012

Case studies – France & UK

	France	UK
Estimated reserves, in TM³	3.9	0.96
Political support	--	++

	Barnett Shales, USA	Parisian bassin, France	Bowland Shale, UK
Well cost (depth 2500m, horizontal drain 1000m, 10 drills contract)	3M$	6M$	-
Fracking cost	2M$	4M$	-
Fracking duration (days)	6	10	-
Total cost (M$)	5-6	10	8-11
Break even price ($/mmbtu)	5-6	10	7-12
Spot gas price ($/mmbtu)	4-5	8-11	8-11

Sources: EIA, 2013 – Bauquis, 2013 - Bloomberg Finance L.P, 2013

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Europe gas supply

- Demand and current import streams;
- Impact of the development of shale gas in the rest of the world;
- Consequences on the evolution of the supply mix.

European gas demand

- The evolution of gas demand:
  - 471 Gm3 in 2011 (10.7% less than in 2010)
  - Still, 1% annual growth until 2020

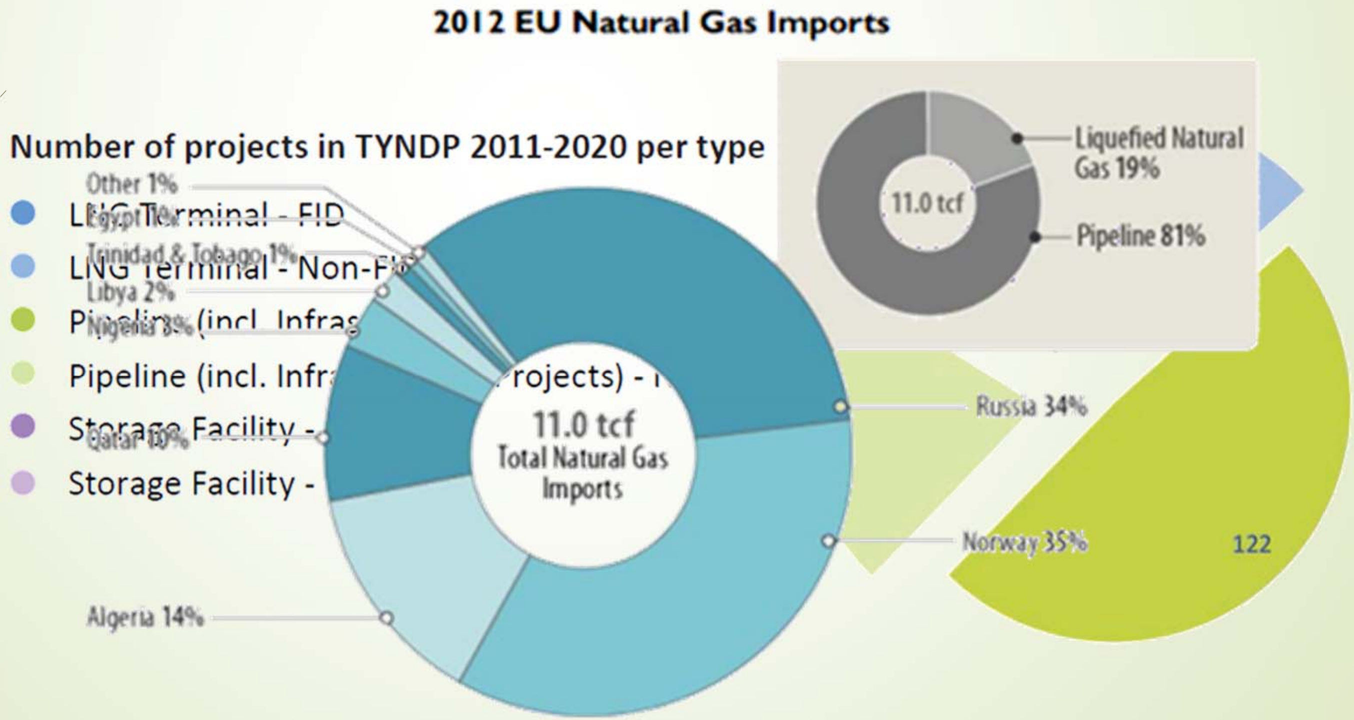
- Share of gas in the EU energy mix: 25% → 30% (2030)

- The longer term evolution depends on the viability of CCS

Sources: Direction générale de l'énergie et du climat, 2011 – Teusch, 2012 – ENTSOG, 2013

Import streams

- Today New projects:
  - South stream from Russia to Italy (63 Gm^3/year for Europe)
  - South Corridor to exploit Shah Deniz II (10 Gm^3/year for Europe)



Sources: Direction générale de l'énergie et du climat, 2011 – BP, 2013 – ENTSOG, 2013

Imports

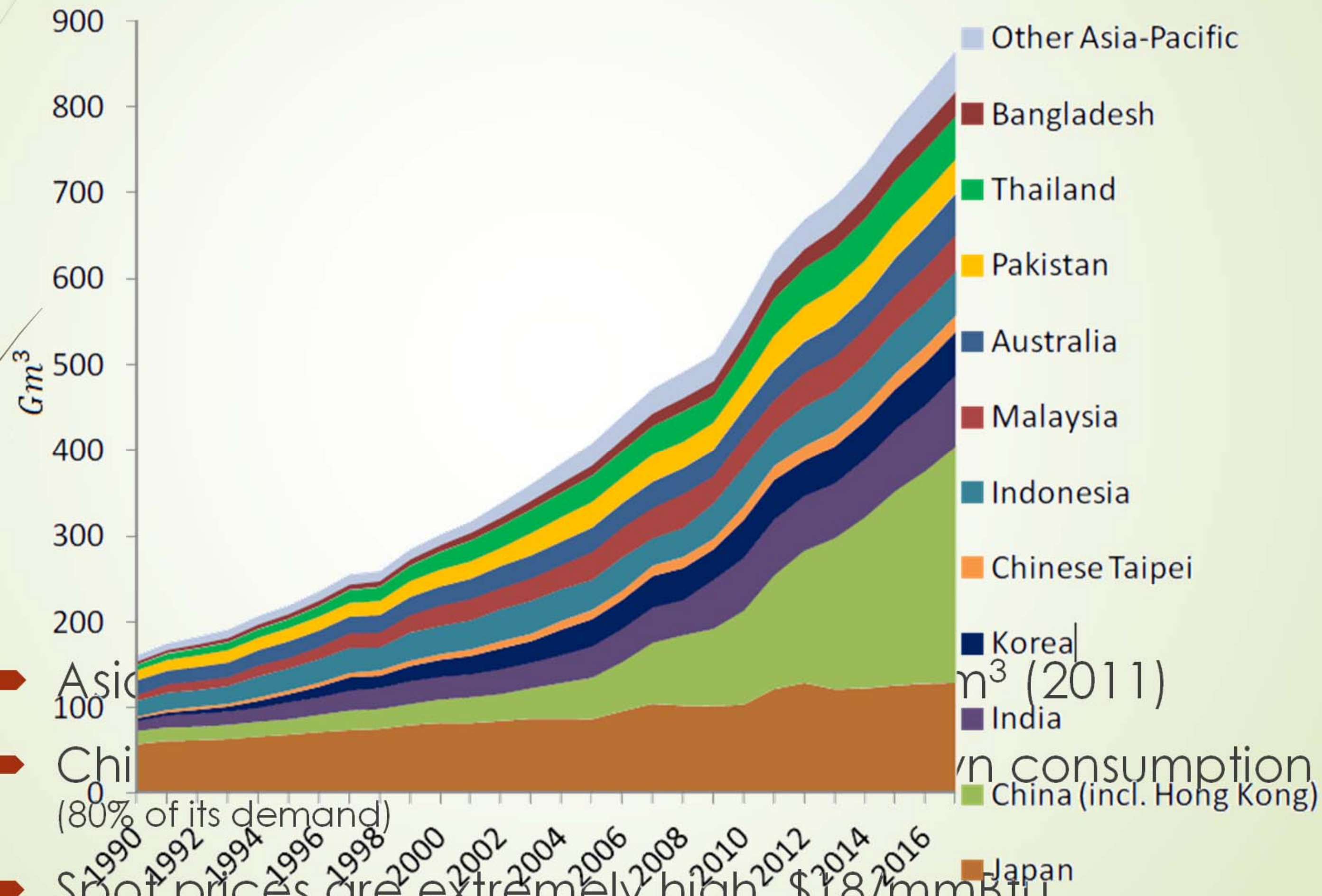
- EU imports: 330 Gm^3 (today) →540 Gm^3 (2035)
- Local shale gas production: not a game changer

LNG

- 150 Gm^3/year LNG potential (2012) → x2 or 3 by 2020
- Full use deemed unlikely:
  - 2,5 times more re-gaseification capacity than liquefaction capacity globally
- More competitive and flexible

Sources: Direction générale de l'énergie et du climat, 2011 – Teusch, 2012

Asian demand



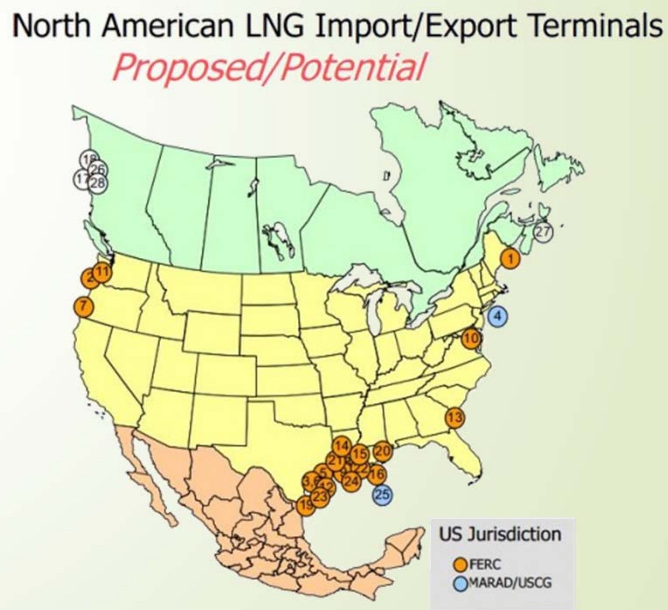
- Asi… m³ (2011)
- Chi… n consumption (80% of its demand)
- Spot prices are extremely high: $18/mmBTU

Sources: Teusch, 2012 – Henderson, 2012 – IEA, 2012

Australian and NA production

	Australia	Canada	US
Exports (Gm^3/year)	120	27	34

- Australia → Asia
- Canada → Asia:
  - Reserves in British Columbia
  - Massive Asian investments
- US → both Asia and Europe:
  - Terminals in the Gulf of Mexico (Sabine Pass)



Sources: Henderson, 2012 – Teusch, 2012 – FERC, 2013

Focus on the US

- Henry hub spot price : 3.5 $/mmBtu

[$/mmBtu]	Henry hub spot price	Liquifaction and regaseification	Transport	Final costs	Region spot prices	Margins
Asia	**3.5**	+ 3.35	+ 3.00	9.85	18	**8.15**
Europe			+ 1.35	8.10	11	**2.90**

- Henry hub break even price : 6 $/mmBtu

[$/mmBtu]	Henry hub break even price	Liquifaction and regaseification	Transport	Final costs	Region spot prices	Margins
Asia	**6**	+ 3.35	+ 3.00	12.35	18	**5.65**
Europe			+ 1.35	10.60	11	**0.40**

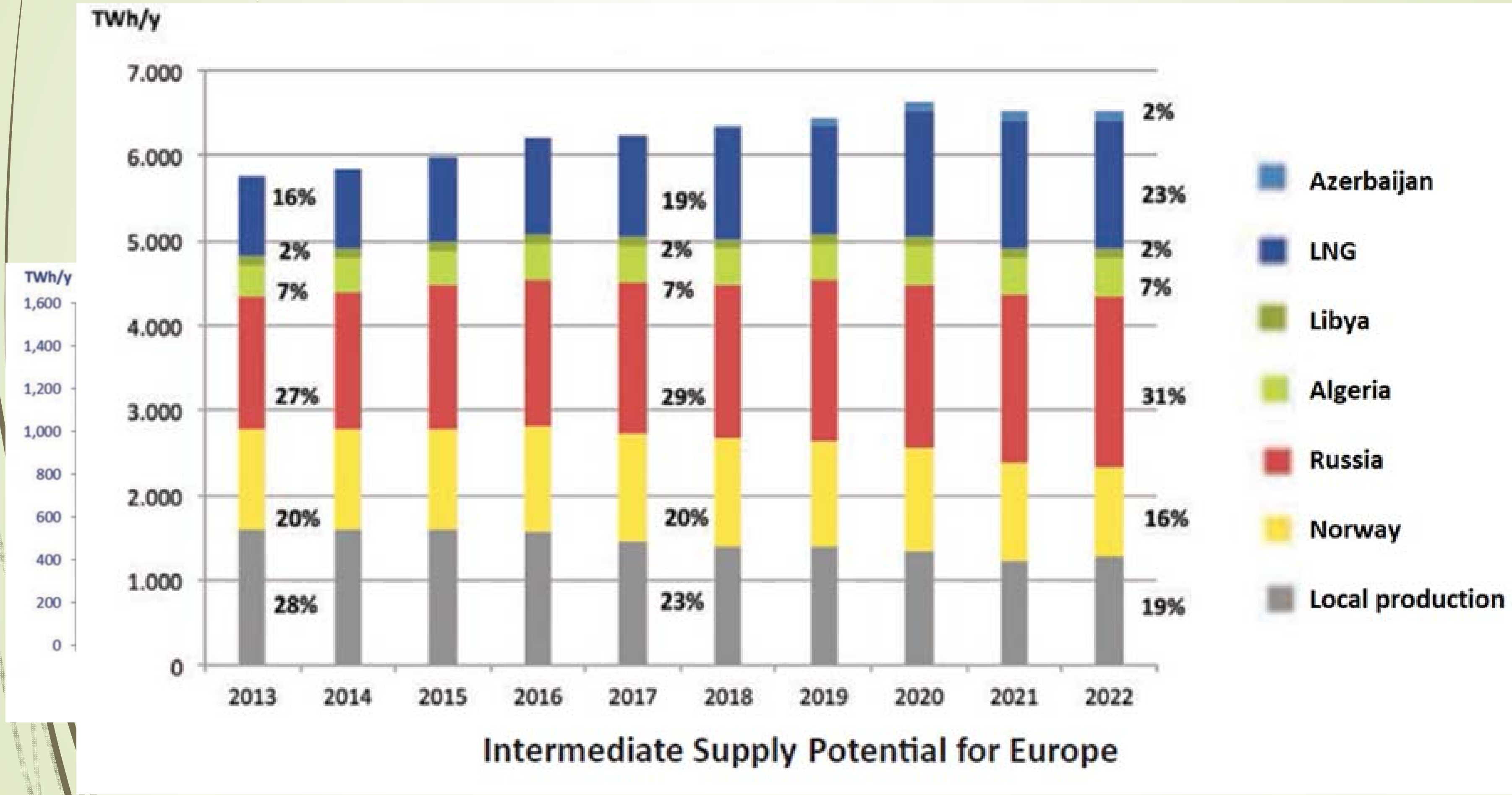
Sources: Henderson, 2012 – Teusch, 2012 – Deloitte Centre for Energy Solution, 2012

Impact of the US self-sufficiency

- Still, US shift will affect Europe
- New LNG streams → bargaining chips for Europe
- Gas-on-gas competition now makes for 50% of Europe long term contracts (20% in 2005)

Sources: Henderson, 2012 – Teusch, 2012

Evolution of EU supply mix



Sources: ENTSOG, 2013

Conclusion

- Estimation of shale gas reserves are quite widespread
- Local production in Europe will at best compensate for the fall in conventional production
- North American LNG exports are unlikely to be more than a bargaining chip for Europe
- European supply mix is likely to stay similar even though the terms could evolve

Thank you!

Main references

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	Production & marketing	Completion & fracking	Drilling & cementing	Preparation (site, suppliers, equipment)	Field developme nt planning	Well evaluation & rights acquisition
R&D costs (lack of geological information)						X
High land costs						X
High service costs	X	X	X	X	X	X
Rig equipment				X		
Geological heterogeneity			X			
Deeper wells			X			
Water Price		X				

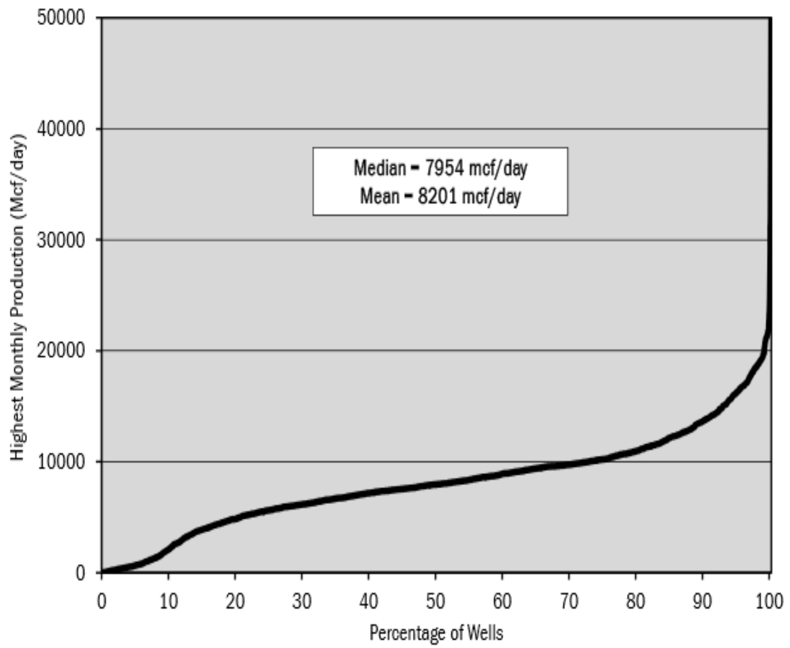


Figure 44. Distribution of well quality in the Haynesville play, as defined by the highest one-month rate of production over well life.[88]

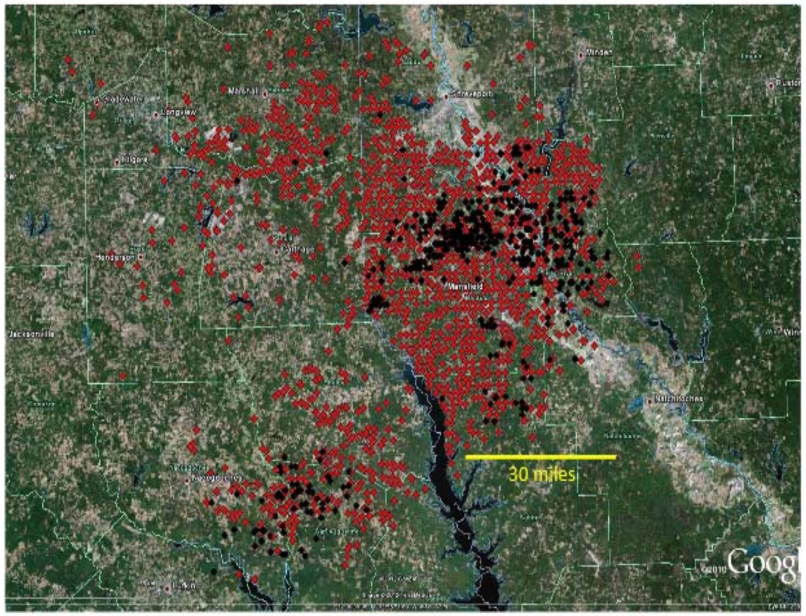
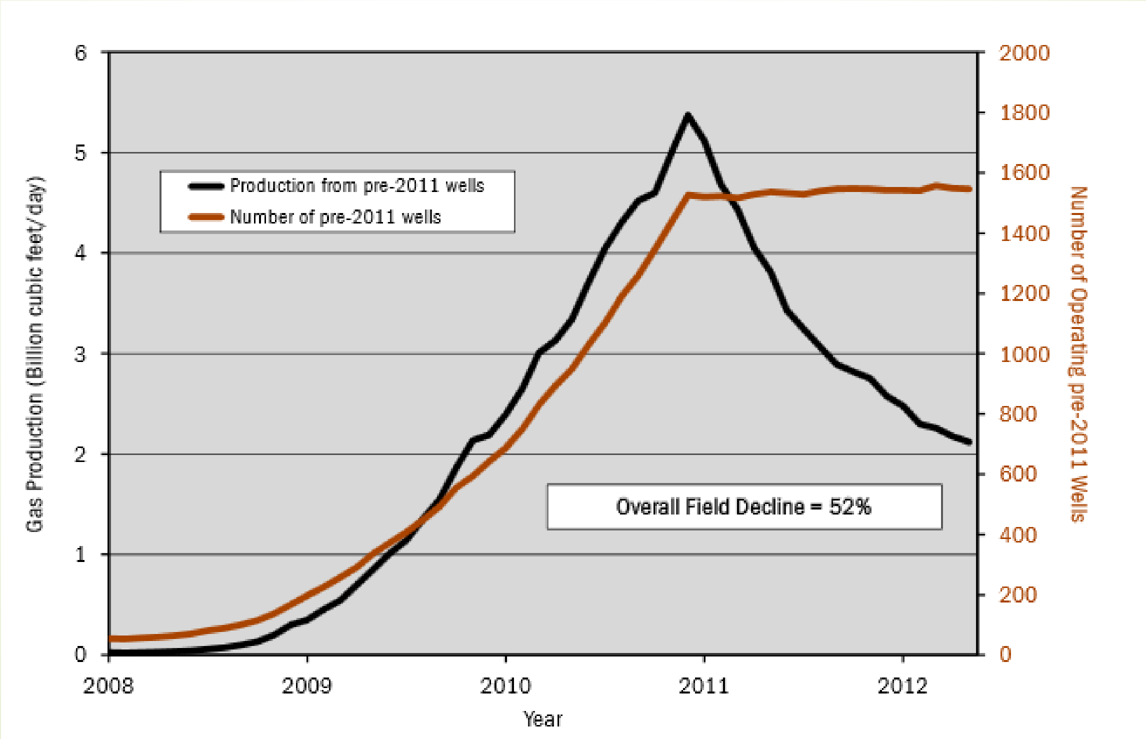


Figure 46. Distribution of wells in the Haynesville play.[88]

Wells in black are the top 20 percent in terms of initial productivity. Many of these sites are multi-well pads with two or more wells. The highest-productivity wells tend to be concentrated in "sweet spots."

Gaz de roche mère

- Les puits voient leur production chuter, de 79% à 95% après 3 ans. Certains puits concentrés dans les sweet spots sont très productifs mais ne représentent que quelques pourcents de la prod totale.



Gaz de roche mère

- L'ensemble du déclin des puits implique que de 30 à 50% de la production annuelle doit être remplacée par de nouveau forages -> ~40 milliards $ d'investissement annuel pour simplement maintenir la prod. (comparaison : le gaz produit en 2012 a rapporté environ 33 milliards de $)

Field	Rank	Number of Wells needed annually to offset decline	Wells Added for most recent Year	October 2012 Rig Count	Prognosis
Haynesville	1	774	810	20	Decline
Barnett	2	1507	1112	42	Decline
Marcellus	3	561	1244	110	Growth
Fayetteville	4	707	679	15	Decline
Eagle Ford	5	945	1983	274	Growth
Woodford	6	222	170	61	Decline
Granite Wash	7	239	205	N/A	Decline
Bakken	8	699	1500	186	Growth
Niobrara	9	1111	1178	~60	Flat

Field	Rank	Number of Wells needed annually to offset decline	Approximate Well Cost (million $US)	Annual Well Cost to Offset Decline (million $US)
Haynesville	1	774	9.0	$ 6,966
Barnett	2	1507	3.5	5,275
Marcellus	3	561	4.5	2,525
Fayetteville	4	707	2.8	1,980
Eagle Ford	5	945	8.0	7,558
Woodford	6	222	8.0	1,776
Granite Wash	7	239	6.0	1,434
Bakken	8	699	10.0	6,990
Niobrara	9	1111	4.0	4,444
Antrim	10	~400	0.5	200
Bossier	11	21	9.0	189
Bone Spring	12	206	3.7	762
Austin Chalk	13	127	7.0	889
Permian Delaware Midland	14	122	6.9	842
Total		**7641**		**$ 41,829**