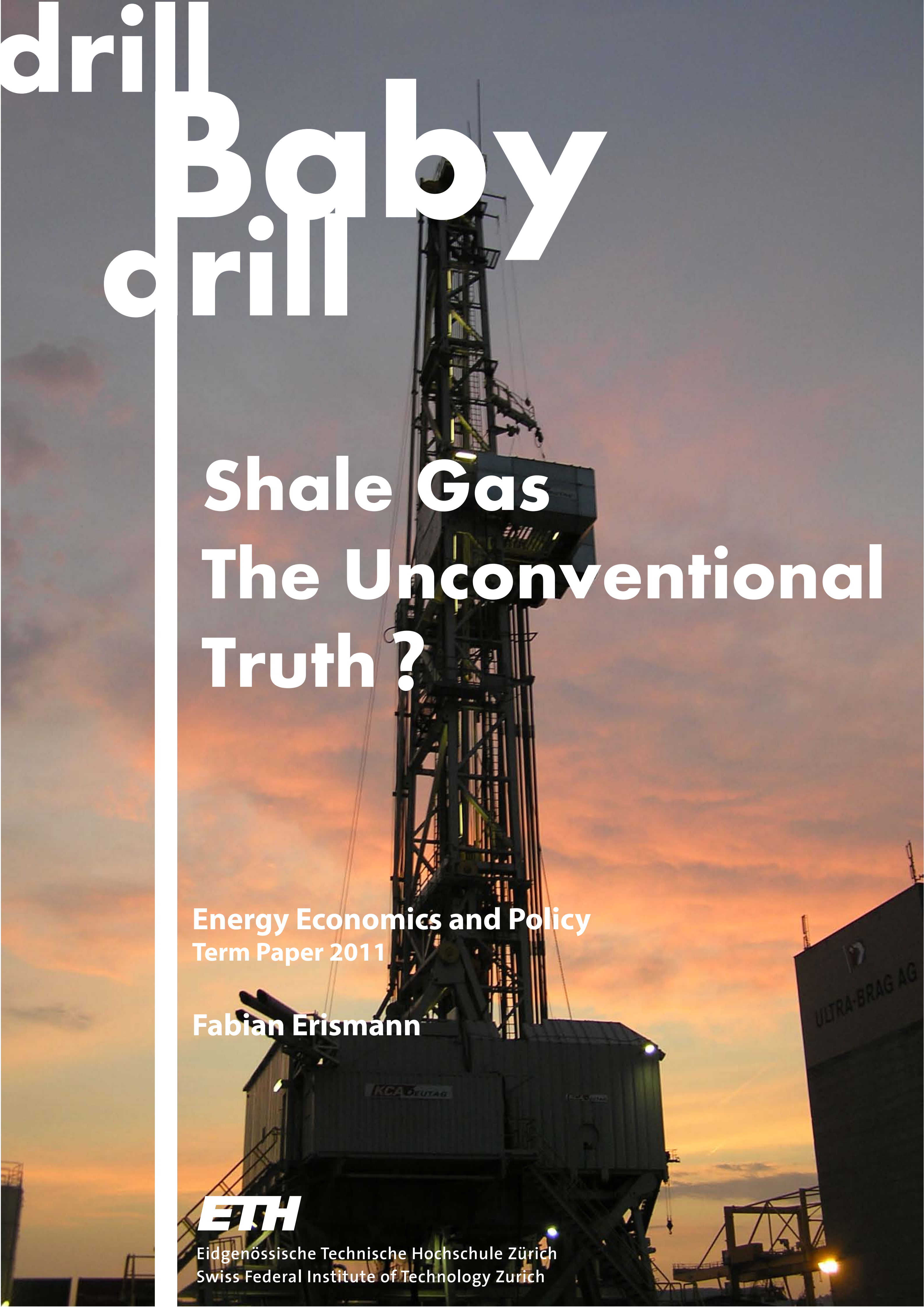

drill Baby drill

Shale Gas The Unconventional Truth ?

Energy Economics and Policy
Term Paper 2011

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"We usually find oil in new places with old ideas. Sometimes, also, we find oil in an old place with a new idea, but we seldom find oil in an old place with an old idea. Several times in the past we thought we were running out of oil whereas we were only running out of ideas."

Parke Dickey, American geologist, 1910-1995

Front image: DEUTAG on-shore rig T-45 in Basel Switzerland. Photo F.Erismann

Introduction

In view of the catastrophic incidents at the Fukushima power plant in Japan, caused by the major earthquake and tsunami, energy policies of countries involved in nuclear power are now debated heavily. Many countries re-evaluate their plans to postpone the planned shutdown of nuclear power plants and to reopen new ones. To prevent energy shortages in countries heavily dependent on nuclear energy will involve fossil fuels in some way or another for the foreseeable future. Exploration and development of shale plays and the production of unconventional gas has risen strongly within the past decade, especially in the United States. The influence of increased gas production from organic rich shales on the U.S gas market is the goal of this paper. Furthermore, environmental issues arising from hydro fracturing, a technique essential for the production of shale gas, will be highlighted briefly, as well as possible solutions to some of the problems discussed. Production figures from 2009 and company forecasts were used in this paper to analyse current and predicted shale gas production in the future and the costs involved with it.

Natural gas is the cleanest fossil energy form that can be transported easily through the existing distribution network and transformed into energy on a large scale. Carbon emissions from the combustion of natural gas are half as much as when burning coal. As renewable energy alternatives are not ready yet to transpose fossil fuel on a large scale, an increased production of natural gas from shale plays may fill the gap of future energy shortcomings in the U.S and may play a much bigger role in North America than in recent years. Due to heavy price pressure on natural gas in the United States, resulting from overcapacities, energy companies have recently become more and more motivated to explore for oil rather than gas.

The result of low gas prices and the oil-spill in the Gulf of Mexico in 2010 was that more and more oil companies moved from deep water exploration into shallow-water and on-shore exploration of hydrocarbons. Furthermore there is a shift taking place from exploring and producing oil instead of gas as margins with liquids are significantly higher than with gas. These supply shifts and the current anti-nuclear climate should provide a base for current gas prices and it can be expected that gas prices will increase slowly in the future as the development of new projects coming into production will slow down.

Unlike oil, the U.S will be able to satisfy its own demand for natural gas for the years to come. Potential resources remaining in U.S shale plays are large and will make the country largely independent from gas imports. This might turn out to be a very strategic benefit when considering the recent turmoil in North Africa and the Middle-East.
In 2010, 10 bcf per day have been produced from U.S shale plays and it is estimated that this figure will increase threefold by 2030.

What is Shale Gas?

Shale gas is a natural gas, produced from its geological origin, mostly an organic-rich, black shale. These specific geological units are the source rocks of hydrocarbons, such as oil and gas. Until recently, oil and gas have been produced from porous and permeable rock formations, so called hydrocarbon traps into which oil and gas migrated after having reached certain thermal maturity grades. These reservoirs are delivering the bulk of oil and gas consumed today.

Due to the complex nature of such trapping conditions, reservoirs of an economic viable size and depth become increasingly hard to find. Although geophysical, geological and drilling techniques to find oil and gas reservoirs have developed greatly in the past decades, the number of new, conventional sources of oil found has decreased since the seventies in the U.S.

Alongside technical breakthroughs in the production and development of oil fields, the actual source rocks of hydrocarbons, the so-called shales, have become more important to energy companies. During the last ten years it has become possible to produce gas directly from the source rock in a commercial manner.

Shales are referred to as sources rocks or "mother rocks" for hydrocarbons, as these rocks usually contain a larger amount of organic material, embedded in fine grained clay debris of different origin. Shale is a geological, descriptive name for a rock that is fine grained. The shale does not necessarily contain a lot of organic rich material, but if it does so, it is often referred to as black shale. The organic rich content is responsible for the very dark, almost black appearance of the rocks.

Shales are the product of intra-basin sedimentation. Fine grained debris and dead organic material such as phytoplankton settles on the ocean floor of sedimentary basins. Such basins have existed throughout time throughout the world in the fore-and back-arc regions of the major plate tectonic zones of this planet. Sedimentary Basins can be very deep and if water circulation in the basin is limited or completely absent the organic matter which is settling down on the ocean floor cannot be degraded fully. The material is conserved under relatively high pressure under anoxic conditions. With time, more and more material accumulates, the shale gets thicker and thicker, and the fine particles get compressed. The result is a dense, very homogeneous looking geological unit; a black shale.

Anoxic events happened frequently and over long period of times from the Permian to the Cretaceous era. Not surprisingly, most of the oil and gas fields can be found during this period of time (the Mesozoic). If and to what extent gas can be produced out of a shale depends on several parameters such as total organic content (TOC), permeability, porosity, thickness and thermal maturity among others.

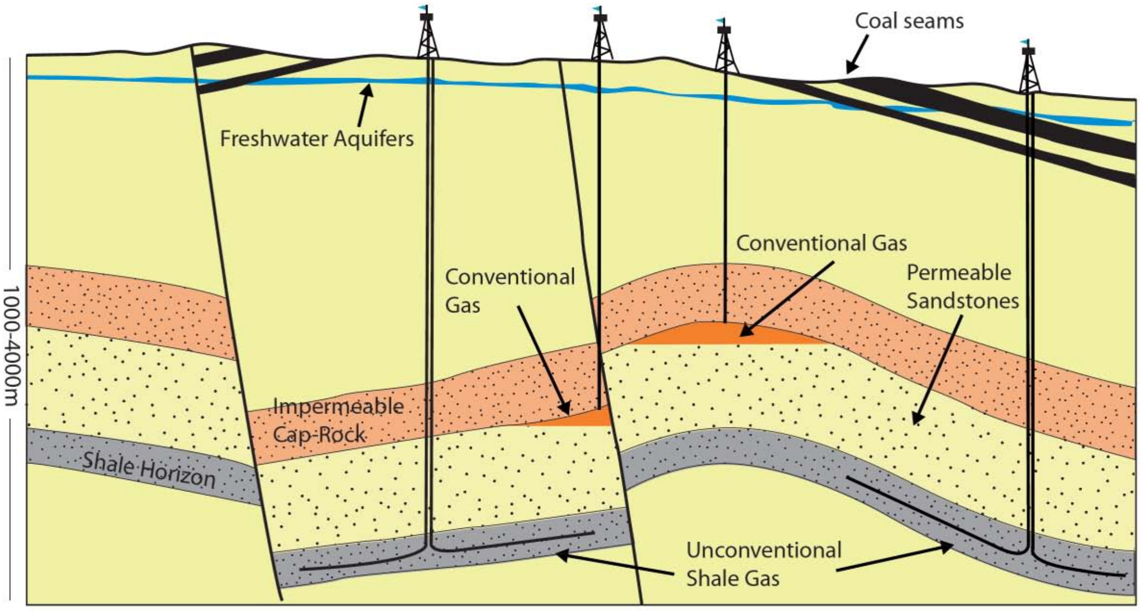

Figure 1: Scematic illustration of different types of hydrocarbin sources. Conventioanl gas is trapped in different geological reservoirs that are caped by an impermeable unit. The source rock of conventioanl oil and gas is very often a organic rich shale. Shale gas is produced directly from these shales using production wells. The depth of the shales vary greatly but are usually lying a substantial distance below the fresh water table in several 100's to 1000's m depth.

***F.Erismann 2011*.**

Shale Plays in the US

Organic rich shales are widely distributed in the US and elsewhere in the world. As such horizons are very common source rocks for conventional oil- and gas plays, it is not surprising that most of the shale gas projects are located in the same geological environments as the major oil and gas fields in the U.S, mainly related to ancient, sedimentary foreland basins of different ages. Production figures and reserves/resources from the following shale plays are used in this report:

-Barnett (US)	*-Woodford (US)*	*-Horn River (CAN)*
-Deep Bossier (US)	*-Marcellus (US)*	*-Utica (CAN)*
-Haynesville (US)	*-Fayetteville (US)*	*-Montney (CAN)*

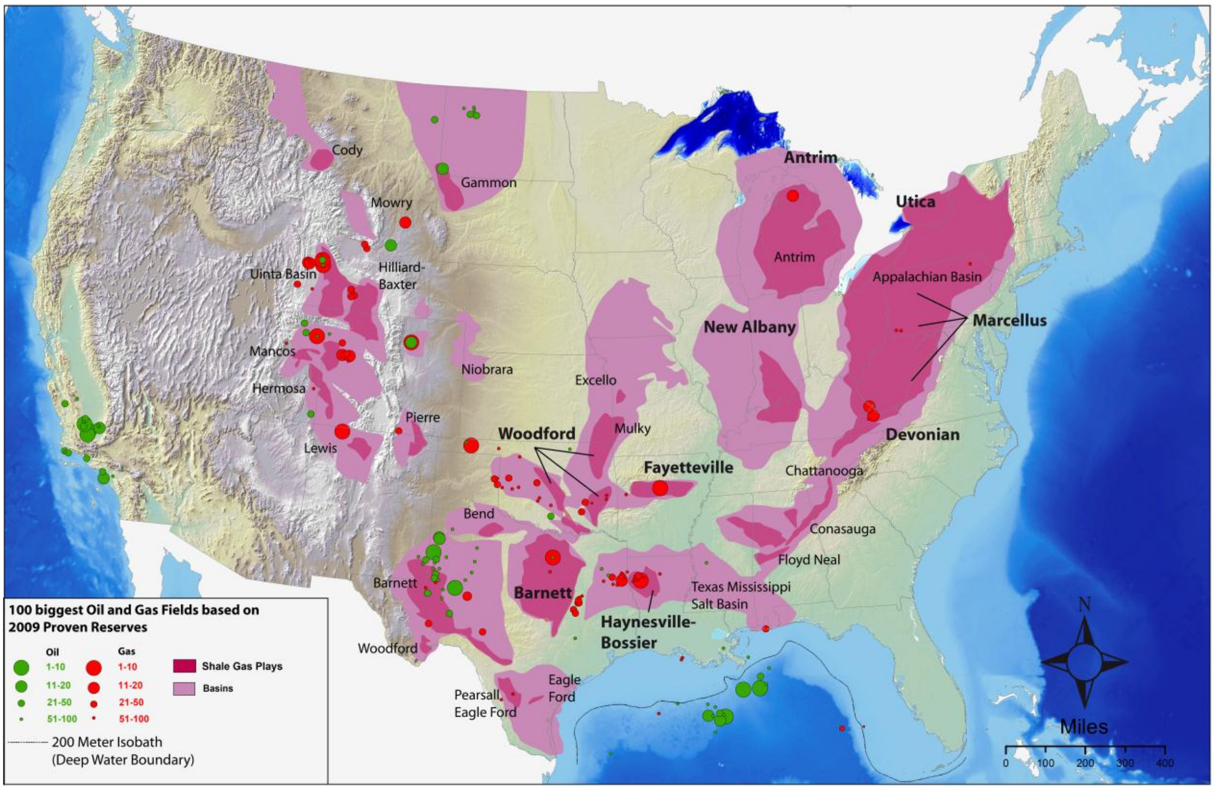

Figure 2: Sedimentary basins and major shale plays in the U.S. The picture also shows the 100 major oil and gas fields. Most of the conventional oil/gas fields are located in sedimentary basins as these areas host the source rocks for hydrocarbons. The Barnett-, Woodford-, Fayetteville-, Haynesville- and the Marcellus shale play are currently the most important ones in terms of shale gas production in the U.S. *Map compiled from EIA and USGS data 2011*.

The deeper the shale, the more technically challenging and costly it is to develop it. According to table 1, the Horn River and the Haynesville shale plays have the largest gas-In-place potential. Most shale gas production is currently coming from the Barnett-, Fayetteville- Haynesville-, and Woodford shales. These plays are located within or close to the U.S Permian basin. West Texas is a very prolific area for both shale- and conventional hydrocarbon development. The Marcellus- and the Montney shale play in Canada are emerging shale plays, currently attracting a lot of interest of several companies.

Table 1: Major shale plays in the U.S and Canada and their key parameters. *Parameters from various company reports and Triston Capital report on natural gas 2011.*

	Barnett (US)	Fayetteville (US)	Haynesville (US)	Woodford (US)	Horn River (CAN)	Marcellus (US)	Montney (CAN)	Utica (CAN)
Depth, m	2,000-2,800	450-2,000	3,200-4000	1,800-2,600	2,000-3,000	1,000-2,000	900-3,000	500-3,500
Thickness	75-200	15-105	60-80	15-60	150-175	15-75	150-300	90-300
TOC %	4.5	4.0-9.5	0.5-4.0	6-6.5	0.5-10	0.4-10.5	2.5-6.0	0.3-3.1
Porosity %	4.5	2-8	8-15	4-12	2-4.5	1.6-7.0	2-8.0	2.2-3.7
Pressure Gradient (psi/ft)	0.46-0.50	0	0	0	0.65	0.45-0.60	0.44-0.70	0
Gas-In-Place, BCF/section	50-150	25-60	200-250	80-300	130-320	20-100	?	25-160

How does Shale Gas Production Work?

Having identified a shale horizon of sufficient size and continuity, several parameters such as total organic content (TOC), porosity, permeability, thermal maturity and depth, thickness and dip of the horizon, need to be assessed. If the parameters turn out to be economically viable, first production test wells are drilled. Due to the fact that most shale plays are under substantial geological cover of several hundreds to thousands of meters, extensive drilling is needed to explore for the most suitable horizon and to produce gas out of it. Vertical drilling is used to identify the exact location of the horizon and as soon it is defined, deviated and horizontal wells are drilled. The shale is then hydro-fractured by pumping water, chemicals and sand into the well under high pressure. Using this hydro-fracturing process, hydrocarbons trapped in fissures and porous parts of the shale will be liberated and transported back to the surface through the production well. Injection wells are normally not used in gas or oil shale projects as he permeability in the shale is too low for injection in one well to be seen in an adjacent production well. This is different from injection of water to maintain pressure in a conventional reservoir, which acts more like a tank. In a shale project, the injection of fracturing fluid and proppants is done in the production well itself.

Technological advances in drilling techniques and the use of chemical components in the extraction process has led to a significant improvement in the recovery of hydrocarbons and the success rate of the various plays in North America and worldwide. Very important parameters for a successful recovery of gas are the natural porosity and permeability of the shale, the gas content, and the viscosity of the gas. Hydro-fracturing and the use of special chemicals can alter some of the parameters in favour of gas extraction.

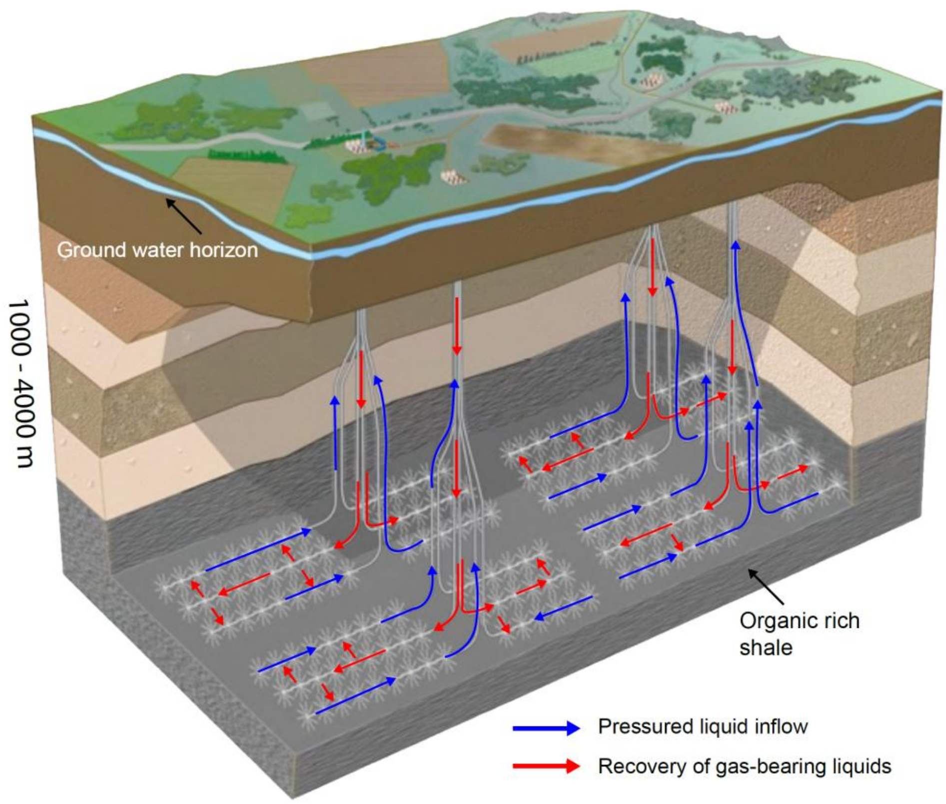

Figure 3: Schematic illustration of production wells of a shale play. As the effect of hydro fracturing is limited to a certain distance around the injection well, multiple wells are needed to reach sufficient extraction volumes of gas out of the shale. ***Modified from Banker Petroleum 2011***

Problems and Risks Related to Shale Gas Production

An argument frequently mentioned is the large amount of water used for the production of shale gas and the possibility of ground water contamination. Several operations have shown that when drilling is done with proper lining and cementation, the risk for groundwater contamination with hydrocarbons and chemicals used in the extraction process can be handled well. Multiple casings and cementations are frequently used when drilling through sensitive ground water-bearing formations which are mainly located close to surface. Furthermore there is often an effective natural sealing mechanism in place which holds the gas inside the shale formation. These natural barriers are very fine grained units in the vicinity of the shale formation, and act as an impermeable barrier. They prevent injected fluids from migrating through the geological column to surface. The same units are also responsible for the natural trapping mechanisms of hydrocarbons. Most wells drilled in the U.S shale plays were drilled at depths greater than 1000 meters, whereas fresh water aquifers tend to be located above 300m below surface. This results in a large geological column lying above the gas-producing shale horizons and any fluid escaping from the targeted shale horizon would need to migrate a substantial distance to surface.

The main risk with the hydro fracturing process is that through pressured injection of liquids into the target area, small seismic events are responsible for the generation of fluid conduits which can reach substantial lengths. Injection tests and seismic monitoring of the hydro fracturing process at the enhanced geothermal system (EGS) project in Basel Switzerland have shown that hydro-fracturing of the target zone can extend to a substantial area but is usually limited in an envelope around the well bore through which fluids are injected. The size and shape of the envelope depends on injection pressure and the geological characteristics of the target formation. The risk that fluids will reach ground water horizons further up cannot be ruled out fully as natural faults and fracture zones do extend to large depths and might act as a pathway for injected fluids.

The large water use is often criticised when it comes to shale gas production. Also here, technology is fast advancing and the industry has come up with specially developed liquids, including propane and other chemicals to reduce surface tension and viscosity of hydrocarbons, reducing the amount of water needed significantly. When putting water usage in perspective with other industries and other fossil energy carriers such as oil and coal, the amount of water used to produce shale gas is significantly lower. To produce one million BTU of energy out of shale gas, 2 to 7 liters of water are needed. One drill hole needs on average 15 million liters, roughly the same amount an 18-hole golf course needs in a month. The fracking fluid from the hydro fracturing process is usually reused, which also limits the amount of water used for a given shale gas operation.

From an atmospheric emission point of view, using natural gas instead of coal or oil firing plants to generate energy would result in much lower CO_2 releases. Despite shale gas being a fossil source of energy, the combustion of natural gas reduces the amount of CO_2 released into the atmosphere by 50% compared to coal fired plants. Nitrogen oxides and Sulphur dioxides released into the atmosphere are lower by several factors when burning natural gas instead of oil or coal. The characteristics mentioned support natural gas, in making it the prime source of energy in the near future. Not only would the shift from oil and coal towards natural gas reduce CO_2 emissions, it would also allow the U.S to decrease the very strong dependency on foreign crude oil imports. Substituting gas for oil in the energy and transportation sector is a step Australia for example, took a long time ago.

U.S Natural Gas Market

Unlike oil and other natural resources, there is no global market for natural gas. Overcapacity in the U.S gas market put heavy pressure on local gas prices starting in 2005. At the moment, continental Europe gas prices are roughly twice as high as the prices in North America. This indicates the strong local footprint and the range of prices in the gas markets worldwide. Looking at the distribution of organic rich shales in the U.S, shale gas reserves are very high and overtake conventional gas reserves. This increase in gas reserves represents a major factor behind the decoupling of oil and gas prices which started in 2005. Prior to this point in time, prices moved in strong relation to each other. Today oil in the U.S costs over four times more per British thermal unit (BTU) than natural gas and U.S gas reserves are very likely to increase further in the years to come. This is not the case for U.S oil reserves which are steadily declining since the 70'ies when peak oil in the U.S was reached. The global financial crisis starting in 2008 led to a sharp fall in both oil and gas prices. Oil prices recovered strongly over the course of the last 12 month whereas gas prices remained at very low levels.

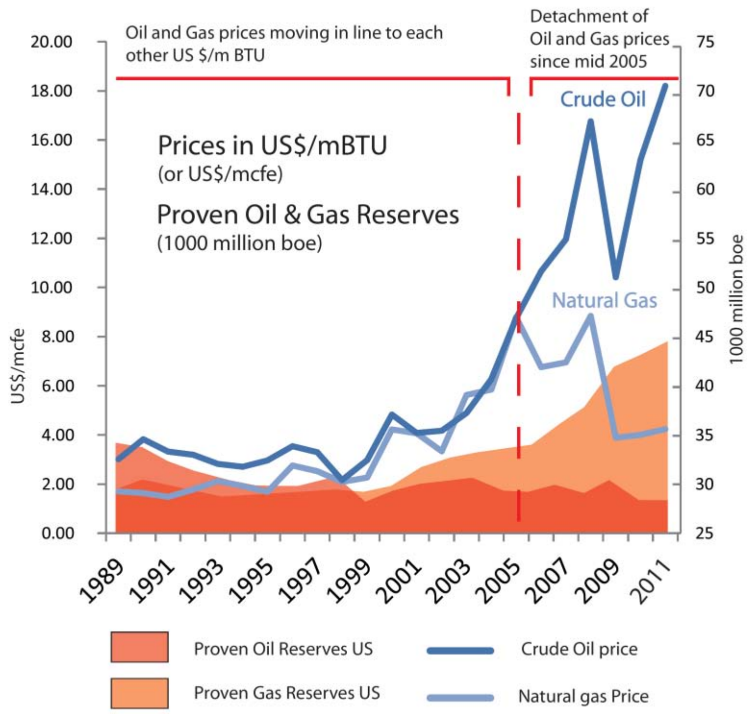

Figure 4: Development of gas and oil prices ($ per BTU) and oil and gas proven reserves since 1989. Oil prices started to decouple from gas prices in 2005. ***Compiled from BP statistical review of world Energy 2010.***

The supply demand situation of natural gas in the U.S is fairly balanced. Since 1990, the U.S became a net importer of natural gas of 2 Bcf per day on average, mainly from Canada and Mexico. Compared to the 70-80 Bcf consumption within the U.S per day, this figure is very low and the U.S would be very capable to satisfy its own demand of natural gas.

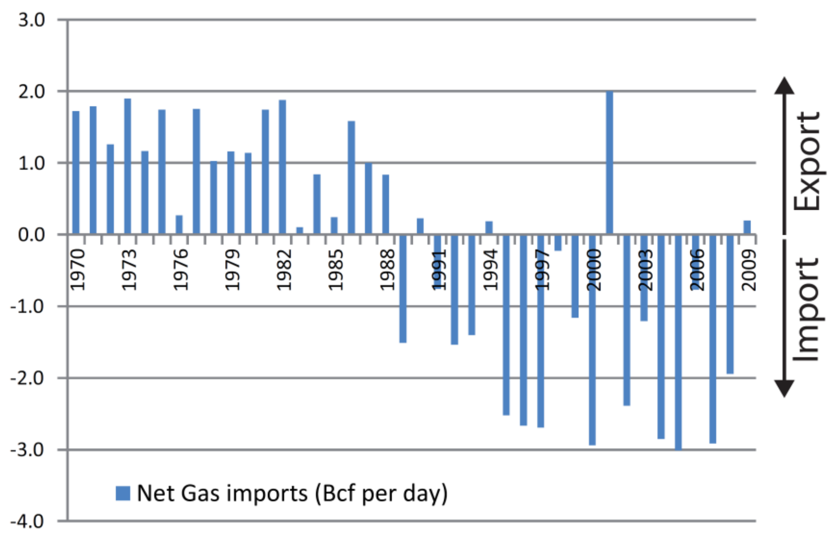

Figure 5: Net import situation of U.S natural gas. Until 1988, the U.S was a net exporter of natural gas and has become a net gas importer, although by very small amounts compared to total daily consumption of roughly 80bcf of gas. Recently, the situation was very balanced and gas consumption in the U.S is almost entirely covered with domestic production. ***Compiled from BP statistical review of world Energy 2010.***

Resources and Reserves

Evaluating gas resource in shale plays is not an easy task and includes a high level of uncertainty, unlike gas reserves, where drilling and geological knowledge is adequate to state a more exact figure. There are two forms of resources, the un-risked- and the prospective risked resource. Based on the reserves and the resource statements of the major companies active in the 9 major shale plays, the production cannot be forecast with a large amount of certainty. In the oil world, "risked" refers to exploration risk, e.g. the chance to make a discovery. It therefore applies to prospective resources. Un-risked or contingent resources refer to resources where a discovery has already been made. There still remains uncertainty associated with contingent resources other than exploration risk. Therefore they are called "contingent" resources and not "reserves" (W. de Meyer; Earth Resource Investments, personal communication). This remaining uncertainty is mainly related to the volume of gas/oil in place, recovery factor, development cost, market risks, permitting issues and price. Only when a sufficient amount of drilling has been performed on a gas/oil play and there is both an approved development plan and, for gas, a gas sales contract in place, a reserve can be stated.

The un-risked recovery potential for the 9 shale gas plays is estimated to be around 743 tcf (Source: Tristone Capital). By 2018, it can be estimated that 24bcf of gas can be produced out of the plays per day, while the majority of gas will come from the Haynesville, Barnett, Woodford- and the Fayetteville shale plays. As development of the major U.S shale plays is still in early stage it can be expected that gas reserves in the U.S will rise steadily in the years to come, given the large extent and the wide distribution of shale formations suitable for gas production in the United States.

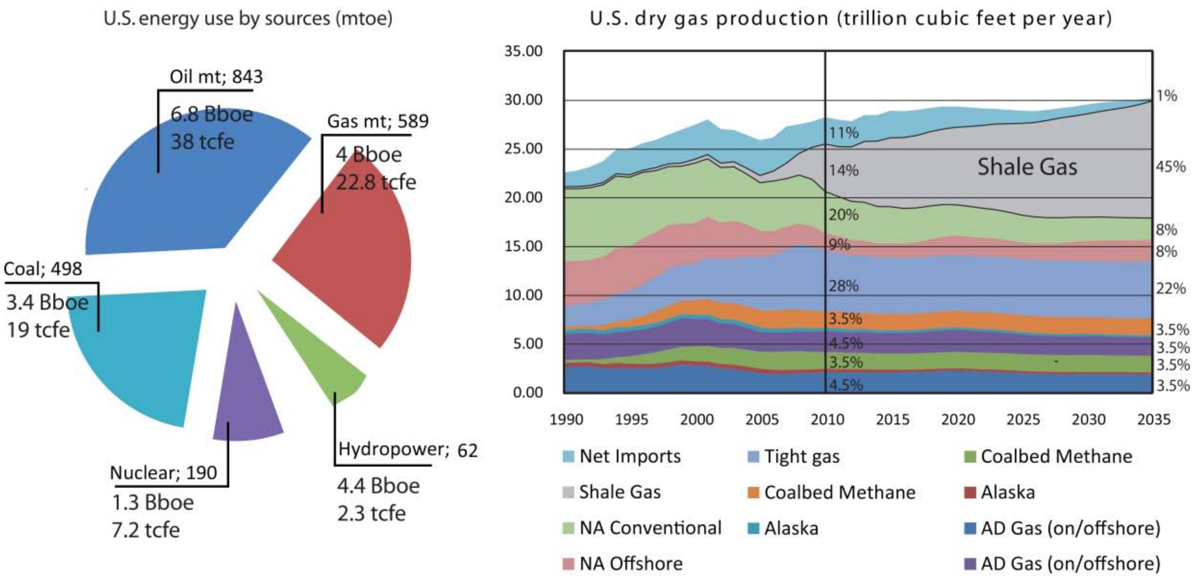

Figure 6: Energy use by sources in the US. Roughly a fourth of US energy is produced out of natural gas. The amount of shale gas has increased steadily over the last few years and it is expected that shale gas may deliver up to 45% of total natural gas produced in the US by 2035. ***Compiled from EIA data and BP statistical review of world energy 2010.***

Companies and Costs

The list of companies involved in the exploration and production of shale gas and liquids in the US is long and includes the majority of oil and gas companies active in the U.S and Canada.
I evaluated shale gas production costs for companies having a market capitalisation above US$ 1000 million. I did not consider companies below this capitalisation level, as such companies are mainly in the exploration and development stage and actual cost of production of these companies do not reflect production cost of the overall shale play.

Modern shale gas development was pioneered by Devon Energy (DNV) in the Barnett shale in Texas (USA) 8 years ago, where they developed horizontal drilling and fracking techniques since

2002. Devon Energy decided to focus entirely on shale gas in the U.S and sold all its international assets. Devon Energy and Cheasapeake are the two companies almost entirely focusing on North American shale gas. In terms of gas production these companies may reflect actual production costs and all in costs best as they are two of the very few pure shale gas producers in the market without any dilution of gas production from conventional sources. Devon Energy still has the lead in terms of production and land holding and is focusing on resource plays onshore North America. Devon also has a large interest in Canadian oil sands projects and to evaluate the costs related to the shale gas business of Devon, the cost for the oil sand projects need to be isolated in this study.

All other producers described in this paper have some conventional sources of gas and oil. It is therefore difficult to analyse the production costs for shale gas only, as such costs are not specifically split within the financial and operating statements of the companies. Due to the relatively large investment required in conventional exploration and production of oil/gas fields, most companies have a portfolio of assets, with an ownership interest in each asset of less than 100%. Even small cap companies could have more than 10 separate assets. In the case of larger companies, with a portfolio including conventional (as opposed to resource play) assets, their portfolio typically consists of tens to hundreds of assets spread across several countries/jurisdictions, with different fiscal/contractual terms and JV interests. Anadarko, for example, has a global portfolio and it is very difficult to extract the actual costs for their shale gas business. This is also the case for Apache Corporation. While the portfolio footprint of these companies is disclosed at the top level, detail at the individual asset level such as resources, costs, terms, etc., are not disclosed.

I specifically looked at production and operating costs per mcfe and the total costs the companies are reporting for their oil and gas business. Production and operating costs only include the up-stream costs of all the wells currently under production or in exploration stage. All other costs, including transport, general and administration and selling costs are not part of production and operation costs but make up a large part of total costs. The companies listed in table 2 make up 70-80% of total shale gas production in the U.S.

Depending on the shale play where the different operations are located and the size of the company, the costs vary substantially and all-in cost for 2009 can be found anywhere between 3$ and 9$ per mcfe. The bigger the company, the smaller the costs, as economies of scale has a large impact on total costs. The larger a company is, the more drill rigs are generally owned, which decreases operating costs and decreases the price pressure from suppliers and service companies. Prices for drill rigs and supply for the oil and gas industry, including piping material has increased dramatically over the last years. Considering the size of Devon Energy and Cheasapeake and the first mover advantage they have within the North American shale plays, it is not surprising that they have by far the lowest cost profile. Furthermore, they give a good indication where costs can be expected as they positioned themselves purely in shale plays without focusing anymore on conventional sources of hydrocarbons.

The other companies observed have increasingly higher costs. Large companies like Anadarko, Talisman energy or Apache have a significant share of conventional oil and gas production. As the risk for conventional oil and gas well development is significantly higher than in the shale plays, production and development costs tend to be higher for those companies. The reason for the higher risk can be found in the very different nature of the two hydrocarbon sources. A shale play, not very different from a coal seam, is easy to explore and to hit with the drill bit as it is exposed over a large lateral and horizontal area. A conventional hydrocarbon trap however is usually very limited in size and shows a rather complex shape and geometry. To drill such a “hotspot” requires a large exploration effort which increases development costs significantly. If drilling of a conventional gas reservoir is successful, the gas can be produced at much lower costs due to the much lower viscosity of gas compared to crude oil.

Company	Ticker	Country	Mcap (B$)	Gas (bcf/yr)	Oil (mmboe/yr)	Total (bcfe/yr)	Prod. & Op. Costs ($/mcfe)	All in Costs ($/mcfe)
Cheasapeake	CHK	US	22280	834	11.8	905	0.97	3.5
Devon Energy	DVN	NA	39610	968	58.0	1419	1.55	3.5
Apache Corp.	APA	NA	48200	576	105.8	1179	2.45	4.2
Range Res.	RRC	US	9100	130	2.5	159	0.84	4.6
Continental Res.	CLR	US	12840	21	10.0	78	1.8	4.9
Petrohawk	HK	US	7003	174	1.5	183	0.43	5.2
Encana	ECA	NA	25030	1037	9.9	1093	1.09	6.2
Whiting petr.	WLL	US	8270	28	14	108	2.1	6.5
Anadarko	APC	NA	41130	809	68.0	1196	1.5	6.8
Talisman Energy	TLM	US	24930	462	73.0	884	1.1	6.8
Crescent Pt. En.	CPG	US	12900	11.2	14.5	94	1.6	7.6
Penn West	PWE	NA	12800	107	37.9	323	2.7	8.3
Petrobakken	PBN	US	3370	8	8.2	54	1.34	8.5

Table 2: Shale gas producers in the U.S. Not all companies listed are pure shale gas producers. The ones entirely focusing their operations on shale plays are Devon Energy and Cheasapeake. Companies listed in this table make up 70-80% of total shale gas production in the U.S. *Data from various company reports.*

Generally the reservoir conditions of the two forms of hydrocarbons are very different. A conventional reservoir, like a sandstone or limestone, usually have a high porosity and permeability, allowing the hydrocarbons to freely flow within these reservoir rocks. The extraction of this gas through the wellhead is therefore relatively easy. Shales however show different reservoir conditions. The interspace between the clay particles is very small and gas particles are isolated from each other and are usually not free flowing. Fracking technology and a high well density are needed to liberate the gas and to bring it up to surface.

A smaller but also relatively cost effective shale gas producer is Petrohawk Energy (HK). In their 2011 capital budget, Petrohawk includes 7 horizontal wells and 35 vertical wells in the Wolffork shale play in Texas. Horizontal well cost estimate is US$ 3.5 million, vertical well cost estimate is US$ 1.7 million per well. An interesting point to bear in mind is the fact that horizontal drilling and fracturing technology is still in a rapidly developing stage and it is not unreasonable to expect big improvements in well production and recovery over the next few years. An example of this is the operations report by Petrohawk where they reported between 32% (high liquids yield) and 37% (gas) improvement in production rates and between 25% and 90% increased estimated ultimate recovery (Howard Weil conference 2011).

The cost analysis of shale gas producing companies has further shown that it is most cost effective to produce shale gas out of the Barnett-, Fayetteville-, Haynesville-and Woodford shale plays. This is the result of a combination of factors, including drilling and completion costs, gas production rates, ultimate recoveries and liquid yields. Generally, shale plays in the Permian basin are well explored and the high level of experience of companies active in these areas might be the major reason why total costs are relatively low. The Marcellus shale is also showing a tendency to low production and development costs and is increasingly attracting interest from energy companies. The cost analysis shows that the average all in costs of the thirteen companies analysed is 5.34 US$ per mcfe of gas. This is substantially higher than current spot natural gas prices of around 4 US$. Most companies would not operate a profitable business with the current low gas prices in the U.S.

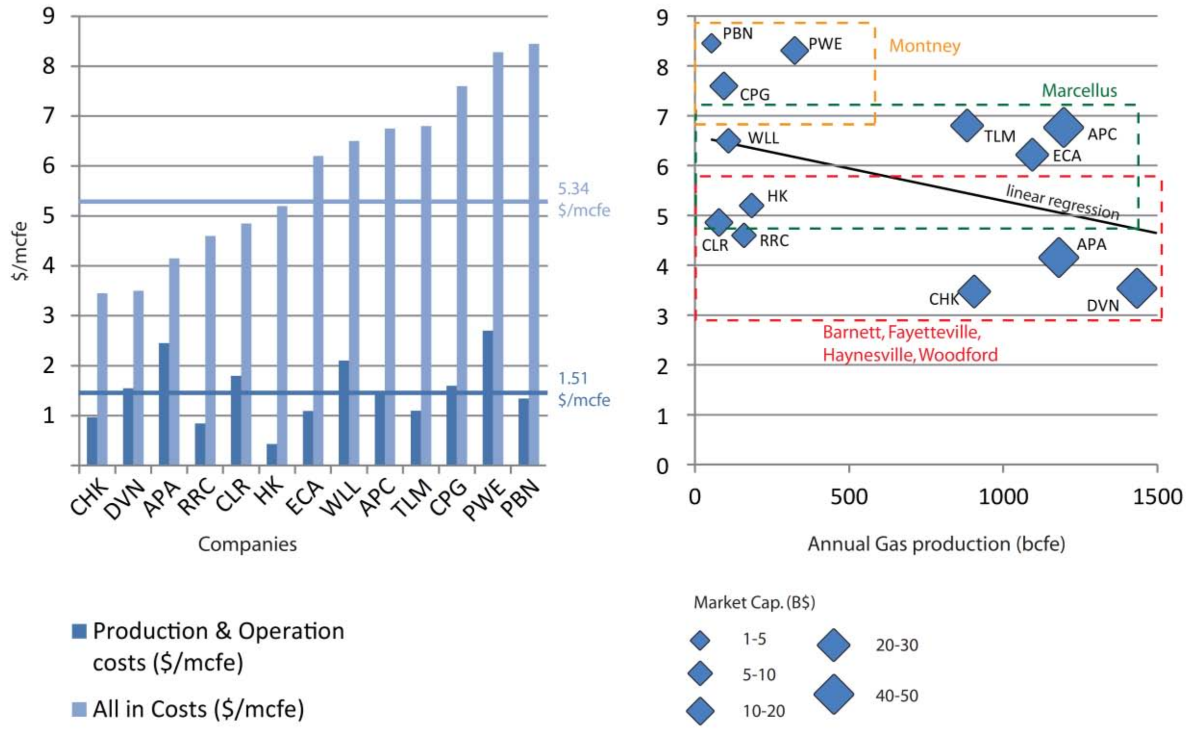

Figure 7: Compilation of total- and production & development costs of selected companies active in shale plays in the United States and in Canada. Total costs differ greatly from company to company. This can be partly explained as not all companies are pure shale gas producer but have a significant amount of oil production in their portfolio. All in costs are generally decreasing with increasing size of the company. There is also a trend for lower production costs for companies producing out of the Permian Barnett-, Fayetteville-, Haynesville-, and Woodford shale, whereas gas production out of the Montney shale seems to come at higher overall costs. ***Data from various company reports***

The high rate of technical improvement and innovation shows that gas reserves are very likely to grow substantially in the years to come. Even more so as the shale plays will develop further as more and more big energy companies like Shell, Chevron and BP enter the shale stage.
First movers in the big shale plays are farming out to majors coming late to the game, thereby reducing their drilling cost significantly, as substantial parts of the costs are carried by the big names farming into Joint Ventures with smaller companies. Examples are Statoil and CNOOC farming in with Chesapeake, Sasol farming in with Talisman, Reliance farming in with Pioneer, KNOC farming in with Anadarko.

Barnett	Fayetteville	Haynesville	Woodford	Marcellus	Montney	Bossier	Eagle ford
		HK			HK	HK	HK
			RRC	RRC			
CHK	CHK	CHK		CHK		CHK	
		ECA					
				TLM	TLM		
FST		FST					
DVN			DVN				
			CLR				
	APA		APA				
		WLL	WLL				

Table 3: Overview of the companies, active in the different shale plays. Devon Energy and Cheaspeake, the two leaders in the U.S shale gas business are both focusing in the Permian shales Barnett, Fayetteville, Haynessville and Woodford and the Marcellus play in the northeast.

Outlook on Future Gas Prices in the U.S

There is a general consensus among the large U.S gas producers that gas prices will remain depressed well into 2012. The main reason for gas prices remaining under pressure is the current oversupply situation in North America. Almost all energy companies exposed to oil and gas production onshore USA are currently transitioning from gas to liquid/oil almost without any exception (Willem de Meyer, Howard Weil conference 2011) after being frustrated by continued low gas prices in the U.S.

With oil prices reaching record levels again in the first quarter of 2011 and low gas prices remaining, the capital programs for 2011 are almost exclusively targeting oil projects. This View is confirmed by Cheasapeake, an ionic gas major, active in several shale plays in the U.S and currently moving to liquids and oil. In 2010, most companies were still drilling gas wells all over the US but the picture has changed completely now.

At current high oil prices, companies exploring and producing gas from shale plays are increasingly coming under pressure as oil production results in much higher margins considering current crude oil prices and dwindling oil reserves in the United States.

Most companies are therefore redirecting their drill rigs to oil targets rather than exploring for gas to take part in the associated, increased profitability when drilling for oil in the current market environment. This trend is likely to continue if gas prices remain at current low levels around US$ 4 per mcfe and is not likely to change until prices rise above US$ 6 or US$ 7, and most companies would be able to produce shale gas with a healthy margin. As this shift is taking place, it is likely that gas prices have reached their low levels and will recover slowly but steadily from here on.

With US gas reserves increasing further in the future there is no fundamental reason why natural gas prices should rally in the short- and mid-term future. Steadily growing gas demand can easily be satisfied with current production infrastructure in the US, making the country independent from large foreign gas imports.

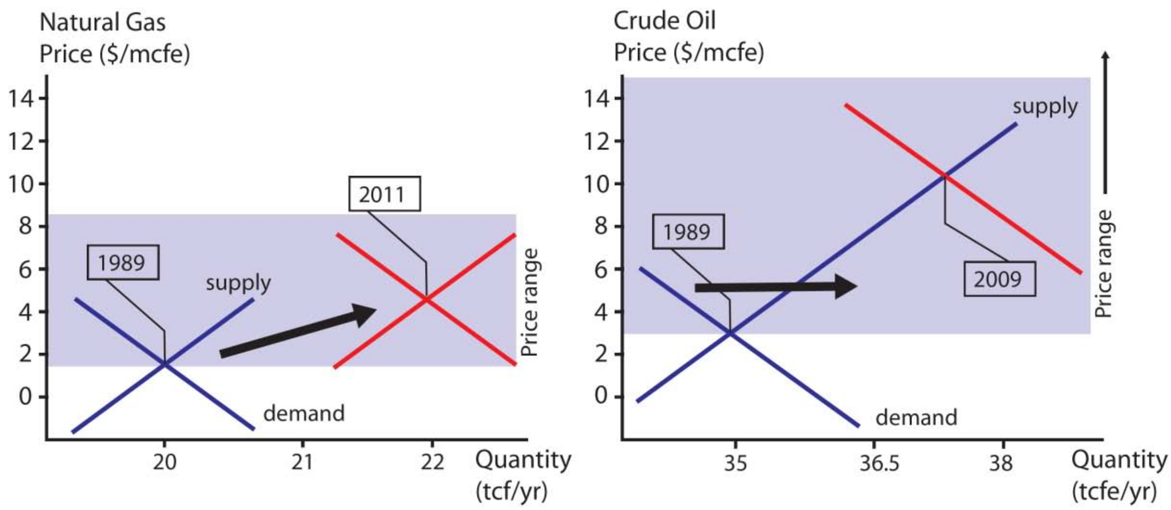

Figure 8: Supply-demand situation for natural gas and crude oil since 1989. Due to the continued increase of natural gas reserves, U.S supply for natural gas has grown in line with demand. As Domestic demand can be satisfied with domestic production, gas prices have moved in a much narrower bandwidth than crude oil prices over the past 20 years. Crude oil prices are much more demand-driven and domestic supply of crude oil has decreased steadily over the last 20 years whereas domestic U.S consumption increased. The unbalanced supply demand situation in the U.S and the global nature of the crude oil market causes oil prices to move in a much larger bandwidth.

The decoupling of oil and gas prices is likely to continue as the reserve situation of these two commodities is very different and the supply situation will tighten even more on the oil side in the foreseeable future. Furthermore it is likely that the very uneven situation in European and U.S gas market will continue, as shale gas development in Europe is still in very early stage but is increasing rapidly, mainly driven by companies such as BNK Petroleum, San Leon and Realm.

Major Oil companies like Shell, again coming late to the party, are farming into Joint Venture projects with small producers and explorers. Overcapacity in Europe is however never at US levels, which is reflected by much higher natural gas price in Europe.

Conclusion

Unrest in the Middle East and Northern Africa as well as the catastrophic tsunami related incident at the Fukushima nuclear power plant in Japan are forcing many industrial countries to rethink their energy policies and to take action to secure their energy needs in a more sustainable and predictive way. In the United States as well as in Europe, shale gas is opening up a whole new potential in terms of domestic energy production. With shale gas reserves steadily increasing over the past years and the favourable characteristics of natural gas compared to coal and other fossil fuels, it can be expected that natural gas, produced from shale formations will play a much bigger role in the U.S. in the future.

This paper tried to outline the costs companies face when exploring and producing shale gas from North American shale plays. The current low natural gas prices will prevent most shale projects from being realised as margins from shale gas sales would simply be too low. The cost analysis showed further, that companies with a first mover advantage like Devon Energy and Cheasapeake, located in the Barnett-, Fayetteville-, Haynesville-, and Woodford shales, are the most cost effective producers and the only ones that can keep all-in costs per mcfe gas produced under the US$ 4 level.

The continued displacement of oil- and gas prices is increasingly shifting energy companies into oil production and away from gas. With gas prices likely to increase in the medium- to long term, future margins of shale gas producers will improve and exploration and development activity will return into the sector. According to industry participants, natural gas prices above US$ 6 or US$ 7 would create interesting margins for the bulk of shale gas producers in the U.S.

Shale gas production in the U.S is estimated to reach 10 tcfe by 2030. This is more than the amount of nuclear energy, about 50% of coal or about a third of total crude oil equivalent used in the United States today. As Natural Gas is capable to replace crude oil in many areas, natural gas has the potential to become the fastest growing and by far the most important energy carrier in the U.S. The demand for natural gas could be provided largely from domestic production and the shift from oil and coal to gas would reduce the CO_2 output significantly. As high oil prices are a large threat to economic growth and oil prices reached record levels in spring 2011 again, the U.S economy could significantly be de-risked if the exposure to natural gas would be increased in the future.

Acronyms and Abbreviations

bls	barrels, petroleum (42 gallons)
bcf	billion cubic feet
Btu	British thermal units
cfe	cubic feet equivalent
EIA	Energy Information Administration
ft	foot/feet
gal	gallon
Mcfe	thousand cubic feet equivalent
MMcf	million cubic feet
Mtoe	million tonne of oil equivalent
ppm	parts per million
SCF	standard cubic feet
tcf	trillion cubic feet
tpy	tons per year
U.S.	United States
yr	year

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