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Game Change? The Many Faces of Today's Energy Revolution

Part I: Technology and Economy, Cause and Consequence

Marie Vandendriessche

Researcher
ESADEgeo Center for Global Economy and Geopolitics

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Introduction

Much ado has recently been made about what has been termed the 'shale gas revolution': the boom in US unconventional gas production driven, in large part, by technological advances. The fortuitous developments in the energy sector have been discussed at length in the media, not only because of their promising economical prospects for a nation some had labeled as in decline, but also for its potential to bring about profound changes in the geopolitical landscape.

This **series of brief papers** aims to be a guide to help contextualize some of the confident claims being made in the media on today's shale gas revolution, offering a variety of factors – economic, political, security-related and environmental – to take into account in order to paint a more multidimensional view of the prospects. Both positive and negative effects stemming from the energy revolution will thus be addressed.

Part I of the series provides critical background information, offering insights on the range of energy sources involved in the revolution, the technology behind their extraction and the economical factors which have propelled the energy boom – and which could present risks of their own. **Part II** presents the geopolitical side of the story, with a detailed look at a number of countries and regions – United States, China, Russia and Europe – in turn, teasing out potential consequences of the energy revolution. **Part III**, which rounds out the series, examines the environmental effects of the energy boom on a local and global level.

The present paper is **Part I of this paper series**, covering essential background to today's energy revolution – which is, importantly, not driven solely by shale gas. The paper first offers a look at the various unconventional sources used to produce energy today and the recoverable reserves in different countries and regions. Thereafter, attention is turned to the technology behind their extraction, yielding clues as to opportunities and risks of the energy revolution. The following section builds on this technical background, asking which geological, technological, economical and regulatory elements have propelled the energy boom forward in the United States. Part I concludes with the economic benefits and hazards of the surge in American production, providing clues to the geopolitical perspectives presented in Part II.

What are the energy types behind the boom, and where are they?

The current dramatic changes in the energy panorama have been strikingly dubbed the **'shale gas revolution'. However, this may be a misnomer**. While the stark increase in energy production in North America is in large part due to an explosive growth in shale gas production, other unconventional hydrocarbon sources are also increasingly being tapped: from **deepwater oil** in the Gulf of Mexico to **tight oil** trapped in the same rock as shale gas, and from **coalbed methane** (CBM) to bitumen extracted from (chiefly Canadian) **tar sands**. Indeed, the **revolution lies mainly in the proportional production increase of unconventional**[1] **hydrocarbon sources as opposed to conventional oil and gas, rather than in the rise of a single energy source (shale gas) alone**. Several of the most prominent conventional and non-conventional sources fueling the energy boom are listed below:

Conventional and unconventional sources contributing to today's energy revolution	
Shale gas	Natural gas trapped in the pores of layers of shale rock, generally spread over a large area. Increased application of the improved technologies of horizontal drilling and hydraulic fracturing have recently allowed a boom in extraction.
Tight gas	Natural gas trapped in relatively impermeable or nonporous hard rock, sandstone or limestone formations. Extracted through the same technologies as shale gas (horizontal drilling and hydraulic fracturing).
Coalbed methane	Methane in a near-liquid state, trapped in the matrices inside coal seams. Often held in place due to the pressure of the water in the seams; extracted by dewatering so the gas can rise to the surface for capture. Sometimes extraction is boosted by horizontal drilling and hydraulic fracturing. *Also known as: CBM, coalbed gas, sweet gas, coal seam gas (in Australia)*
Tight oil	Light crude oil trapped in the same shales as shale gas, and extracted through the same technologies (horizontal drilling and hydraulic fracturing). *Also known as: light tight oil*
Oil sands	Loose sand or rock material saturated with bitumen (tar), a very viscous and heavy form of petroleum. Extracted through surface/strip mining or *in situ* techniques: injecting steam into the subsoil to separate bitumen from sand. *Also known as: tar sands, bituminous sands*
Deepwater sources	Oil and gas in deposits in - sometimes ice-filled - deep water. Previously left untapped because of difficulties in extraction such as geology, operating costs, and environmental risks.

[1] Note that 'unconventional' gas is an ambiguous term, as the 'conventionality' of a resource is a shifting concept. The International Energy Agency (IEA) defines 'unconventional gases' as "part of a gas resource base which has traditionally become been considered difficult or costly to produce".

It is important to remark that the quantities, location and distribution of the world's nonconventional reserves are still under exploration[2]. However, in its special report on unconventional gas published earlier this year, the International Energy Agency (IEA) estimated that the technically recoverable **resources of unconventional gas worldwide approach the size of remaining conventional resources,** which stand at 420 trillion cubic meters (tcm). The distribution of the unconventional side of this equation was estimated as follows:

Type of unconventional gas	Shale gas	Coalbed methane	Tight gas
Estimated technically recoverable reserves, in trillion cubic meters (tcm)	208	47	76

According to the same report, at end-2011:

Half of the **USA**'s remaining recoverable resources of natural gas were unconventional, with the full total of gas resources representing around 110 years of production at 2011 rates. The deposits are distributed across the country, however coalbed methane resources are found mainly along the Rocky Mountains. Some of the major shale reserves are the Marcellus shale in the northeast (New York, Pennsylvania, Virginia, Ohio), the Haynesville formation in the south (Louisiana, Arkansas, Texas), and the Bakken shale, which crosses the Canadian border. The distribution among the various unconventional sources is:

Type of unconventional gas	Shale gas	Coalbed methane	Tight gas
Estimated technically recoverable reserves, in trillion cubic meters (tcm)	24	3	10

China's unconventional gas resources were as of yet fairly uncharted, however they are "undoubtedly large". Remaining recoverable resources of unconventional gas (almost 50 tcm) far outstrip remaining conventional gas resources, by a factor of 13. Geographically, the non-conventional resources are concentrated mainly in the far northwest (Junggar Basin) and the center (Ordos and Sichuan Basins), with some presence in the northeast. The distribution is as follows:

Type of unconventional gas	Shale gas	Coalbed methane	Tight gas
Estimated technically recoverable reserves, in trillion cubic meters (tcm)	36 [3]	9	3

In **Europe**, Poland and France are estimated to have the largest shale gas reserves, followed by Norway, Ukraine, Sweden, Denmark and the UK. Coalbed methane resources

[2] Note also that estimates of recoverable resources vary widely. For a detailed description of these varying estimates and the reasons for the differences, see the European Commission's Joint Research Center report *Unconventional Gas: Potential Energy Market Impacts in the European Union* (2012).

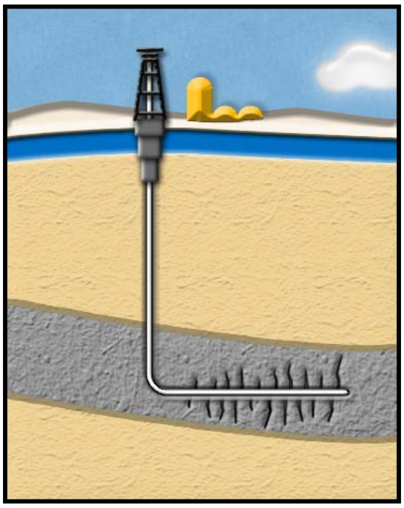
[3] However, note that official Chinese figures published in March indicated recoverable shale gas reserves to be at 25 tcm.

are also present, mainly in Ukraine, the UK, Germany, Poland and Turkey. For the OECD Europe countries, at end-2011, the IEA estimated the distribution of non-conventional gas reserves to be as follows:

Type of unconventional gas	Shale gas	Coalbed methane	Tight gas
Estimated technically recoverable reserves, in trillion cubic meters (tcm)	16	2	3

How are unconventional hydrocarbons extracted?

As mentioned above, **technological advances** are one of the main factors behind this most recent energy revolution. Shale gas is not a newly discovered resource: its existence has been known for decades, but its extraction was **not economically or technically feasible until recently**. Because this 'unconventional' gas is trapped in dense pores spread widely throughout the layer of shale rock, the vertically drilled wells used to extract conventional hydrocarbons were only able to release a very limited proportion of the gases underground. However, the combination of horizontal drilling and hydraulic fracturing (*fracking*) technologies – which are not new, but have been vastly improved – has radically changed extraction volumes and prospects. Consequently, these technologies have truly taken off: whereas fewer than 10% of the US wells were horizontal in 2000; currently that proportion stands at 80%.


Technologies of shale gas extraction*

Modern day shale gas wells are started by drilling vertically down to the shale rock layer[4]. The **drilling then shifts to a horizontal phase**, with the horizontal sections extending for up to several kilometers each. **Hydraulic fracturing**, the second revolutionary technology, is applied after the drilling phase is complete. A liquid known as fracturing fluid[5] is pumped into the well at high pressure in order to 'crack' the rock, opening fissures or fractures which radiate out from the well bore for tens to hundreds of meters: these channels allow the gas trapped inside the rock to escape.

After the initial fracturing (which can be applied in a single or multiple stages), the well starts producing a mixture of flowback water and gas. Initially, the proportion of hydrocarbons in this output is low, but it increases rapidly as the volume of flowback water decreases. A large

[4] Each drilling pad can hold a single or multiple wells, thus increasing potential yield.
[5] Fracking liquid exists in various compositions, but it is typically made up of a high proportion of water combined with a complex blend of chemicals, as well as particles (sand, ceramic beads, or others) which become lodged in the fissures to prevent them from collapsing after the initial injection. Other types of fracturing liquids include foamed fluids and hydrocarbon-based fluids.
* Graphic design: © Katrien Vandendriessche

amount of gas (mostly methane) is often **vented** into the atmosphere during this phase; alternatively, it is **flared** (i.e. the hydrocarbon content is burned off in a controlled fashion). Venting and flaring are the one of the main causes of the high levels of greenhouse gases emitted during the production of unconventional hydrocarbons. Once the flowback period (which can last for a number of days or weeks) is over, the **hydrocarbon content of the output increases sharply** and collection and production spikes. However, the sharp burst of valuable and highly concentrated output typically only lasts for a year or couple of years, after which there is a **steep decline** and **very limited output for the rest of the well's life**[6].

Despite technological advances and economies of scale, the **production of shale gas remains expensive** when compared to conventional gas. A typical shale well[7] costs some $8 million, while a conventional vertical gas well in the same geographical area would cost only $3 million. The price difference lies mainly in the well completion cost (the fracking stage(s)), which make up roughly 60% of the total cost in a horizontal shale well with a long lateral section – as opposed to 15% in a conventional gas well.

Note also that shale gas **production costs vary widely** depending on geological factors such as depth of the reserves and pressure. These factors are highly favorable in the case of the USA; in contrast, continents such as Europe are not as geologically fortunate. The **USA presently holds a strong cost advantage** due to the combination of, *inter alia,* geological features, economies of scale and concentration of technical know-how.

Which factors contributed to the American boom?

According to the US Energy Information Administration (EIA), US shale gas production was nearly non-existent in 2000 – by 2012, annual production exceeded 225 billion cubic meters. This sudden boom, baptized the 'shale gas revolution', was caused by a cluster of **geological, technological, economical and regulatory** factors, examined below.

The strong US **cost advantage** described in the previous section is one of the elements behind the 'revolution', but it did not come about in a vacuum. For instance, the **technological advances** that made shale gas (and tight gas and oil) production economically feasible were propelled forward by both market and geopolitical determinants, such as **high global oil prices** and the **quest to quell dependence on outside sources**.

Another factor, which has been unequivocally fundamental, is the natural geological blessings of the USA, such as the **size of its recoverable reserves** and the **depth and**

[6] Based on experience on the Barnett Shale Play Paul Stevens wrote in a 2010 Chatham House Report that shale wells might only have a life of 8–12 years, compared with 30–40 years for a conventional gas well.
[7] The typical shale well here is the one taken as a reference by the IEA in its Golden Rules Report.

pressure of its wells. Maximizing these natural benefits has been possible, in part, because of such characteristics as the **low population density** on certain shale formations (such as North Dakota's Bakken Shale) and the dense and developed pre-existing infrastructure of the American **pipeline network**.

Economical and regulatory factors are in play as well: **high-risk private capital investment**, for example, has arguably been instrumental in the novel exploration and development of the shale gas reserves. This high-risk capital investment is further facilitated by federal and state **regulation of land rights** in the US: because private land owners hold the rights to the oil and gas beneath their land, they are able to privately (and lucratively) lease it to drilling companies.

It is important to note that this cluster of factors has served to benefit more than the shale gas revolution alone. While recent media coverage has focused primarily on the shale gas ingredient, the energy boom in the entire North American continent is actually **multifaceted**, with strong contributions coming from the bitumen from **oil sands** (chiefly in Canada) and from **tight oil and deepwater petroleum**.

In a context of dropping natural gas prices (described further in the following section), focus has been shifting away from shale gas production alone. This has led, for example, to increased interest in shale sites with a higher proportion of liquid hydrocarbons (which retain higher market value). The necessary **diversification of sources** has been sped along by applying the twin technologies of horizontal drilling and hydraulic fracturing – initially used primarily for shale gas extraction – to tight oil and tight gas extraction, which have also become much more feasible. In fact, the reference case used by the EIA in its Annual Energy Outlook (AEO) 2012 sees both strong increases in natural gas production[8] and in domestic production of petroleum and other liquids[9], including biofuels.

What are the economic risks and opportunities?

Such an extreme surge of comparatively cheap energy (after more than a decade of increases, real natural gas prices have been dropping steeply since 2009, and are now approaching levels of 1980) could have **profound effects on US manufacturing prospects**. **Competitiveness of exports** stands to improve considerably; the term **'reindustrialization'** is even in circulation. A Citigroup analysis published in March asserted that the energy boom could create 2.7 to 3.6 million net new jobs and add 2 to 3% to real GDP by 2020. Activity in the petrochemical sector and related industries could be enhanced

[8] Estimated growth of 1.0% per year, allowing the US to become a net gas exporter by 2022. Shale gas will account for almost half of this production by 2035, up from 23% in 2010.
[9] Set to rise by 3.1 million barrels per day from 2010 to 2035.

further by the inflow of large volumes of **Foreign Direct Investment** (FDI), as investors may reason that prospects are arguably more secure in North America than in the volatile Middle-East.

Nevertheless, euphoria can be blinding, and there are some **caveats** to be addressed. Firstly, **on the production side**, it is obvious that the costs of shale gas extraction cannot continue to fall indefinitely. With natural gas prices dropping vertiginously in parallel with a slowing decrease in production costs, the **profit margin of shale gas** – which is still much more costly in production than conventional sources – is **diminishing**. This may affect the commercial viability of the energy source. Changes in (environmental) regulation, which is still under revision or even construction, may cause further cost increases. Secondly, shale gas presents a number of **difficulties related to consumption and export**. For one, natural gas is not fully fungible. Applications in the transport sector, for example, are currently scarce. In addition, because gas cannot easily, safely and economically be transported in its gaseous state, possibilities for export depend heavily on liquefaction capacity.

Another danger pointed out by some analysts is the possibility that a **shale bubble** is growing. In recent years, there has been somewhat of a 'land grab' in energetically valuable parts of the American territory: for example, in the Eagle Ford shale play (Texas), the cost of drilling rights increased from less than $4,000 an acre at the start of 2010 to more than $20,000 an acre in November of that same year[10]. Investment in drilling rights and gas leases, both by domestic and foreign actors, has been massive. However the profitability of many of the purchased drilling sites is highly uncertain and sometimes under-researched. Geological idiosyncrasies, variable well recovery rates and dropping national gas prices, among other factors, lend a high level of risk to these investments. As such, the soaring prices of drilling rights may not always be justified[11].

Conclusion

Part I of this paper series has sketched a technological and economic picture of the current energy revolution. Each of the factors presented holds clues as to the risks and potential of this ongoing trend. One of the main elements to consider is that, despite the oft-used label

[10] according to analysis of transaction data by IHS, a research group, cited in The Financial Times
[11] Moreover, legal analysts have warned of significant dangers of gas leases on mortgaged lands: not only are homeowners usually unaware of their liability in case of environmental damage caused by often underinsured and risky resource extraction on their lands; but there is also a serious risk to the secondary mortgage market and even to US economic recovery. In the November/December 2011 edition of the New York State Bar Association Journal, Elisabeth N. Radow describes in detail how potential or real damage caused by drilling could lead to mortgage defaults (even the mere act of a homeowner signing a gas lease on a mortgaged property, which usually occurs without lender consent, may provide reason for termination of the lease, and thus potential default). As drilling companies are also underinsured, the costs of such defaults could fall on the $6.7 trillion American secondary mortgage market, and possibly on taxpayers. This poses a serious risk for US economic recovery as well, because its measurement is based partly on indicators such as construction starts and new mortgage loans - which could be impacted severely by the phenomena described above.

‘shale gas revolution’, the current boom in US energy production is **not driven by shale gas alone**. The technologies behind shale gas exploration have opened up avenues for other unconventional hydrocarbons such as tight oil and tight gas, which may indeed prove to be more profitable than shale gas itself. Deepwater drilling for crude oil and extraction of tar from Canada’s oil sands provide further additions to the energy boom.

Reserves of the world’s unconventional hydrocarbons are still under exploration. However, the IEA estimates that technically recoverable resources of unconventional gas worldwide approach the size of remaining conventional resources, thus **truly changing world energy perspectives**. Reserves on the American continent have been explored most completely, revealing high volumes of shale and tight gas, while other country’s reserves are lesser known.

However, even if all resources were charted, extraction prospects are not. The revolution in energy production is currently concentrated in the USA because of a **unique cluster of drivers and advantages which ensures the energy revolution will not be easily replicable**, at least in the short term, in other countries and continents. Stark improvements of the twin technologies of horizontal drilling and hydraulic fracturing have been critical to the American success, but advantageous geological conditions, regulation, economic incentives and high-risk investment have also played significant roles.

All of these conditions have come together to provide **immense economic benefits for the USA**, including the prospects of ‘re-industrialization’ driven by cheap energy prices, a potential inflow of FDI, and a burgeoning petrochemical industry. Elation over these prospects, however, should be tempered in light of a number of **looming risks**, such as the shrinking profit margin and thus diminishing commercial viability of shale gas. It is also important to recall that natural gas is as of yet not a replacement for the energy-thirsty and petroleum-reliant transport sector. In addition, the much-touted export opportunities of unconventional gas are far from guaranteed, pending government approval of exports as well as improvements in liquefaction capacity and export facilities. Lastly, the high-risk investment that helped fuel the boom may also be creating a dangerous potential real estate bubble.

In part II of the paper series, the economic opportunities and risks described above will form the basis for a look at the possible geopolitical implications of the energy production revolution. The US, China, Russia and Europe will be examined in turn. Finally, the series will conclude with an examination of the environmental impact of natural gas, both on local and global levels, in order to round out this panoramic and multifaceted view of the current energy revolution.

ESADE
Ramon Llull University

For further information on ESADEgeo's Position Papers, please feel free to contact:

Marie Vandendriessche

ESADEgeo Center for Global Economy and Geopolitics
Av. Pedralbes 60-62, 08034 Barcelona, Spain
+34 934 95 21 46
marie.vandendriessche@esade.edu

www.esadegeo.com
http://twitter.com/ESADEgeo