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December, 2011

# The Economic Impacts of Shale Gas Extraction: Moving Beyond Jobs and Tax Revenues

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## EDI Quarterly

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### Editor's Note

by Jacob Huber

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Welcome to the December edition of the EDI Quarterly! This issue features contributions on unconventional gas and green gas. Two perspectives from the US are presented, discussing issues surrounding the exploitation of unconventional gas there in addition to an explanation of the technical issues surrounding shale gas and an overview of European developments. The section on biogas discusses recent developments, a decision support tool for investments, certification of green gas, and a perspective on injection into the Dutch natural gas grid. Finally, a new section is devoted to brief summaries of interesting conferences members of the Intelligence Unit at EDI have recently attended.

The themes of the next Quarterly will be gas quality and smart grids. Should any of our readers be interested in making a contribution in either of these areas please contact us at the address that you can find below. We hope that you enjoy all of the interesting contributions in this issue.

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# Shale gas in Europe: replication of American success or a concealed illusion?

By Nadja Kogdenko

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***The shale gas revolution in the US is frequently cited as one of the major highlights of the world's energy industry over the last decade. The growth in shale gas production in the US since 2001 has led to significant changes in the national energy market. Until recently the United States appeared to be on the verge of becoming one of the world's largest importers of liquefied natural gas (LNG).***

However, the development of two innovative technologies – hydraulic fracturing and horizontal drilling – has enabled the economical production of indigenous unconventional gas reserves in the US, leading to the emergence of larger domestic gas supplies, mainly coming from gas trapped in the shale formations (so-called shale gas). Today, shale gas represents around 20% (4,87 trillion cubic feet or 138 billion cubic meters) of the total US gas production, and it is expected to reach 50% by 2035<sup>1</sup>. This growth is astonishing given that shale gas represented only 1% of the total US gas production in 2000<sup>1</sup>. Due to shale gas developments, overall US natural gas production in 2009 overtook that of Russia, taking the world's top producer position and transforming what had been the largest gas consumer to a potential gas exporter<sup>2</sup>. The successful development of shale gas in the US has intensified the search for these reserves globally. With regard to Europe, recently several European countries, such as Poland, Bulgaria, Romania and others, have begun looking to shale gas as a means of improving national energy security and decreasing gas import dependence on Russia. Until now several shale gas exploration activities have already been initiated in Europe, however, the question whether the American shale gas success can be replicated in Europe still ends with a big question mark. This article aims at providing a broad overview of the shale gas potential in Europe and its current developments, giving an insight into the main challenges Europe might face with respect to shale gas production, and how these compare to the situation in the US.

## Shale gas developments in the US

The idea of producing natural gas from shale formations is not new. In small quantities, shale gas has been produced in the US since the 1940s<sup>3</sup>. However, due to the low productivity of shale wells and high costs, the production of this gas was considered a small-scale niche and therefore did not attract much attention from oil & gas majors. In essence, shale is an organic-rich sediment but, compared to a sandstone, which is a conventional reservoir of natural gas, shale has low porosity and permeability – poor properties for the production of gas and therefore resulting in a low well productivity. Techniques for natural gas production from shale formations have improved over time. However,

a significant breakthrough was reached only in 1991 when George Mitchell, the American geologist, combined the techniques of horizontal drilling and hydraulic fracturing, allowing greater yields of shale gas, setting the stage for the American shale gas revolution<sup>4</sup>.

Inherently, the horizontal drilling technique allows a greater length of the shale deposits to be in contact with the well bore, while hydraulic fracturing produces cracks in the reservoir, enhancing the migration of gas to the well bore. The use of these techniques was perfected by smaller companies and by oilfield service companies, eventually building the production of shale gas to levels where it became a significant part for the US gas industry. Today, shale gas represents about 20% (138 billion cubic meters) of the total US gas production, and it is expected to reach 50% by 2035<sup>1</sup>.

The developments in the shale gas industry can be demonstrated by the example of the Southwestern Energy Company practices in the Fayetteville shale from the first quarter of 2007 until the second quarter of 2009<sup>6</sup> (Figure 1). The figure shows that in just over two years, time requirements for drilling one horizontal well decreased by 45%, while the average length of a horizontal section of the well almost doubled, resulting in a significant increase of the average shale gas production rate. At the same time, the production costs (drilling and well completion costs) remained nearly unchanged. This partly can be explained by the fact that the production of shale gas in the US is located in a vicinity of gas consumers, in this way omitting gas transportation costs. With these improvements one rig could produce more wells on the annual basis, overall resulting in more than five-fold increase of the annual shale gas production<sup>6</sup>. This example might rise the question of the extent to which shale gas resources are limited in the US. The US Energy Information Agency (2011)<sup>12</sup> estimates technically recoverable US shale gas reserves at 862 trillion cubic feet (24,5 trillion cubic meters), which is about 3 times the amount of proven recoverable reserves of natural gas and 100 years worth of consumption at present rates of usage<sup>7,8</sup>.

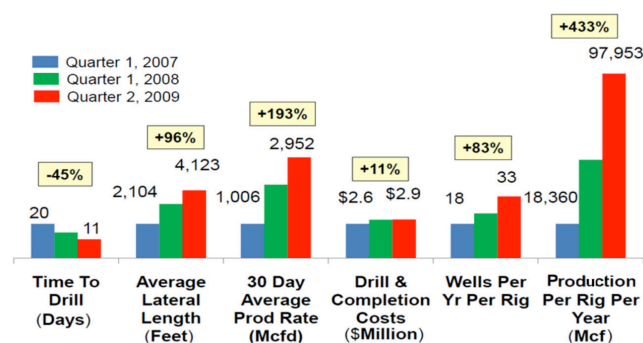


Figure 1. Efficiency improvement in shale gas production. Best practices of Southwestern Energy Company in the Fayetteville shale formation<sup>6</sup>

1 CERA (2010). *Fueling North America's Energy Future. The Unconventional Natural Gas Revolution and the Carbon Agenda. Special report.* Cambridge Energy Research Associates.

2 Tallents, A. (2011). *European gas supply and demand, and the outlook for shale gas. Analysis, Vol. 45. No.3.*

3 Atlantic Council (2011). *European unconventional gas developments. Environmental issues and regulatory challenges in the EU and the U.S.*

4 Ivanov, N.A. (2010). *Shale gas. FAQ. Material for the seminar "shale gas revolution: risks and opportunities for Russia".*

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7 Data on world's natural gas reserves. Available at <http://dolgiikh.com/index/0-39>

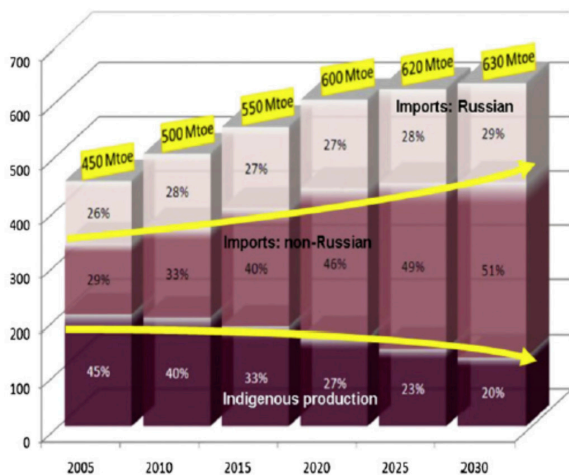


Figure 2. Projections of indigenous gas production and non-EU gas import for a panel of 25 EU Member States (excluding Norway)<sup>9</sup>

### Trends in European gas supply

Facing the success story of shale gas developments in the US, various countries around the world hope to duplicate this success in their own territory.

With regard to Europe, indigenous reserves of natural gas are declining and the following situation in gas market can be observed. In 2009, natural gas accounted for 25% of the primary energy need in Europe compared to only 10% in 1973, and this share is expected to grow in the future. According to a study of Weijermars et al. (2011), natural gas consumption in Europe is expected to reach 650bcm in 2020 and 680bcm in 2030, while its indigenous production will decline from 230bcm in 2020 to 140bcm (~130Mtoe) in 2030 (Figure 2). Statistics of the International Energy Agency (IEA) show that from the 22 European OECD members, only Norway, Denmark and the Netherlands still have sufficiently large gas reserves to cover domestic demand<sup>10</sup>. This indicates that Europe is facing an increasing dependency on gas imports, including intercontinental LNG and pipeline gas. Already this year (2011), gas import accounted for nearly a half of Europe's gas supply, and it is expected to reach 80% by 2030<sup>9</sup>. Altogether this demonstrates the importance of shale gas development in Europe for the reduction of growing gas import dependency and energy security problems. However, there are many factors, which can hinder this development and need closer consideration (discussed later). Currently, exploration for shale gas across Europe is still in its infancy and no production is foreseen in the short term.

### European shale gas potential

The first estimates of Europe's unconventional gas resources in place were presented in a paper by Rogner (1997), who estimated some 1255 Tfc GIIP, of which 549Tcf (15,3Tcm) would come from shale gas and remaining - from other sources of unconventional gas, such as tight gas and CBM (coal bed methane)<sup>11</sup>. The recent study of the US Energy Information Administration (2011)<sup>12</sup>, however, estimates 15Tcm of technically recoverable shale gas resources in Europe. The fact that the

current estimates of technically recoverable shale gas are higher than GIIP estimates by Rogner (1997) is partly due to the exclusion of Poland, Hungary and Romania from Rogner's assessment (particularly Poland, which holds a substantial shale gas resource base), since appraisals for these countries were not available at that time. Other sources<sup>13,14</sup>, also suggest that shale gas volumes are likely to outweigh the remaining conventional gas reserves in Europe, however the exact number still remains undetermined.

According to Tallents (2011), around 50 companies are currently active in shale gas exploration in Europe, ranging from the majors, such as Exxon Mobil, Shell, Total, Conoco Philips, and Chevron, to small state oil & gas companies (Figure 3). The majority are involved in data acquisition for appraisal purposes. A number of international oil companies, led by Exxon, have already obtained exploration licences in Poland, Hungary, Germany, Romania, Sweden and the UK, however, most of the majors have focused on Poland, where there are significant shale deposits with a geology similar to the Barnett Shale in Texas (first play, where the economical production of shale gas begun)<sup>5</sup>. From all European countries Poland holds the largest shale gas reserves, nearly 5,3tcm<sup>10</sup> (Figure 4). With the current annual consumption of 14bcm, of which only five billion are produced within the Polish borders, shale gas reserves of such a scale could entirely sustain Polish gas needs for centuries to come and enhance energy security across the Central and Eastern European countries.

Given the country's 70% gas import dependency on Russia, the government is keen to support shale gas development by evaluating reserves, offering attractive fiscal terms and issuing large numbers of licenses<sup>2</sup>. Until the present, around 100 licenses have been issued to international and state oil & gas companies for shale gas exploration and production, however, the deputy minister Maciej Grabowski has recently indicated that the potential commence of shale production can

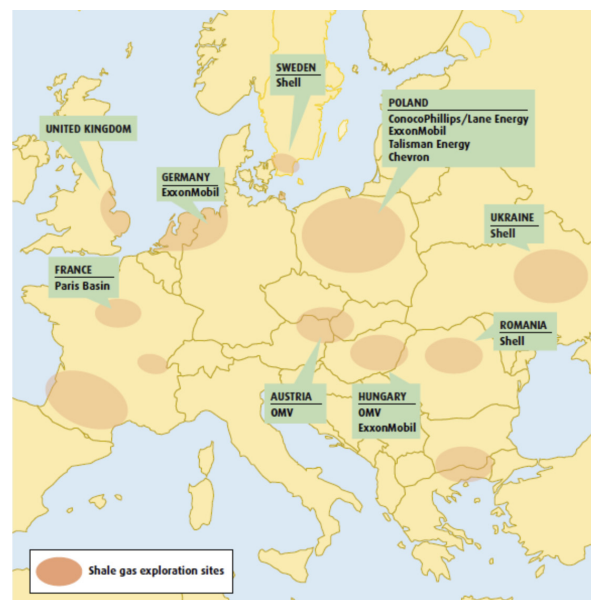


Figure 3. Shale gas exploration sites in Europe<sup>2</sup>

8 Kefferputz, R. (2010). *Shale Fever: Replicating the US gas revolution in the EU?* CEPS Policy Brief No. 210. June 2010.

9 Weijermars, R., Drijkoningen, G., Heimovaara, T.J., et al. (2011). *Unconventional gas research initiative fore clean energy transition in Europe*. *Journal of Natural Gas Science and Engineering*, 3, 402-412.

10 OECD/IEA (2010). *Natural gas information 2010*, International Energy Agency. 594 p.

11 Rogner, H. (1997). *An assessment of world hydrocarbon resources*. *Annual review of energy and environment*, 22, 217-262.

12 EIA. (2010). *World shale gas resources: an initial assessment of 14 regions outside the United States*.

13 CERA (2009). *Multi-client study, gas from shale-potential outside North America?* HIS Cambridge Energy Research Associates. February 2009.

14 Geny, F (2010). *Can unconventional gas be a game changer in European Gas Markets?* Oxford Institute for Energy Studies.

15 Overbeek, E. (2011). *Shale gas doesn't make Poland the new Norway yet*. *European Energy Review*, June 14, 2011.

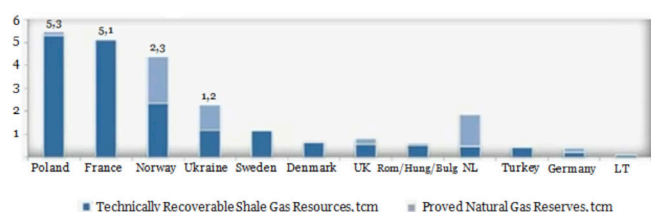


Figure 4. Estimates of technically recoverable shale gas resources in Europe<sup>10</sup>

be expected at earliest in 2015. The development of Polish shale gas is estimated to take longer than the US, partly due to the time needed to gain expertise, a lack of pipeline infrastructure and the necessity to address public concerns (discussed later).

Next to Poland, the Ukraine is also putting a lot of effort into encouraging shale gas exploration activities, in order to decrease its energy dependency on Russia. According to Tallents (2011), in January 2011, after resolution of several tax and licensing issues, it was announced that Shell would start shale exploration activities in the eastern Ukraine. TNK-BP is already exploring in the eastern Ukraine with the state owned Neftogaz Ukrainy. Meanwhile, other international companies are also getting involved in exploration activities in this region. Recent data show that the first hydraulic fracturing test in Ukraine has already been completed (the first of its kind in the eastern European country), resulting in shale gas flow rates of around 65 thousand m<sup>3</sup>/day, which is a rather promising result. Besides Poland and Ukraine, substantial shale gas reserves are found in such European countries as France, Norway, Sweden, Denmark, the United Kingdom, Romania, Hungary, Bulgaria, the Netherlands, Turkey, Germany and Lithuania (Figure 4). However, there are various challenges in the way of their development.

### Europe's main challenges

One of the major potential problems in Europe with shale gas production is the geology, which is less promising than in the United States. In general, shale deposits in Europe are deeper and the basins themselves are smaller and more fragmented compared to those in the North America. According to Stevens (2010), European shales are richer in clay, making these deposits less amenable to hydraulic fracturing and hence economically less attractive. Kefferputs (2010) mentions that while the break-even gas price for some US shale plays is estimated between \$3 and \$7/mmbtu, for Europe this number would be above \$10/mmbtu<sup>8</sup>.

Another major obstacle facing Europe with shale gas production is the density of population, which is about 5 times higher than in the US. For economically viable shale gas production, several drilling rigs and wells are required to be placed relatively close to each other, together with new road and pipeline infrastructures. In this regard, Europe simply does not have much space compared to the US. In addition, Europe is lacking experience with shale gas production and facing significant equipment shortages. The US is a 'home' for many rig facilities companies and an experienced drilling workforce. In 2008, the US had more than 2000 active onshore gas-drilling rigs while in Europe, as of April 2010, this number was only around 1008.

Nevertheless, acceptance by local communities is likely to present the major challenge for the developments of shale gas in Europe. Not only is Europe more densely populated than the US, European citizens do not have any financial benefits from shale gas production on their land in comparison to the US situation. In the US, the mineral rights are owned by local residents, which they can sell, making a substantial profit. (For more about regulation, please read the piece by Professor Dianne Rahm from Texas State University) For instance, in the New York State some residents were offered \$5500 an acre, with 20% royalties on whatever gas is extracted<sup>8</sup>. On the contrary in many EU countries these rights are owned by the state, which leaves local residents with only few benefits<sup>8,19</sup>. In addition, one could argue that environmental awareness in the EU is higher than in the US, which could lead to a particularly strong public opposition due to possible contamination of drinking water supplies. Large quantities of water (about 20,000m<sup>3</sup>) in combination with sand and chemical additives are required to fracture one well (more about hydraulic fracturing, water use and environmental impacts of shale gas production read in the article of N. Rop in this Quarterly edition). Even though horizontal drilling occurs at a depth of around 1000 to 3000m (depending on the shale formation) and the deepest aquifer layer which could be used for drinking water purpose is located at around 200m, people have high concerns about potential groundwater contamination by the chemicals used in the process of hydraulic fracturing. France, which has the second largest shale gas reserves after Poland, has imposed a moratorium on horizontal drilling and hydraulic fracturing until sufficient research on economic, social and environmental impact of shale gas development is performed. This decision was based on the strong opposition and protests from environmental organisations and residents living in the vicinity of proposed shale gas development activities<sup>2</sup>. In the US, this issue is also being raised more and more. For instance, officials in Philadelphia also asked their state regulator to ban hydraulic fracturing until its effects, particularly on drinking water, are sufficiently studied<sup>8</sup>. Currently, the chemicals used in hydraulic fracturing are exempted from the Safe Drinking Water Act of the US, making the technology more easily exploitable compared to the EU, where there is a set of strict environmental regulations<sup>2</sup>. At the moment the US Environmental Protection Agency (EPA) is conducting a study on the impact of hydraulic fracturing on drinking water, taking a full life-cycle assessment into consideration. This study is expected to be ready by 2012.

### Concluding remarks

Despite the fact that several European countries have high hopes for shale gas developments and therefore reduction of their energy import dependency on Russia no shale gas production is currently taking place within Europe or is foreseen to emerge in upcoming years. In line with all the existing challenges, public acceptance currently remains the primary one to the development of shale gas in Europe. In case the current EPA research in the US concludes that hydraulic fracturing technique indeed poses a real danger regarding groundwater contamination and has other related environmental risks, this would likely to slow down European shale development even more. Altogether, it makes it fairly unlikely that a similar shale gas revolution will take place in the EU in the near-term, transforming its gas market in a similar way to that of the US.

16 <http://www.upstreamonline.com/live/article291801.cce>

17 <http://www.naturalgaseurope.com/polish-hydrocarbon-tax-in-2015-3776>

18 <http://www.naturalgaseurope.com/kulczyk-oil-ventures-announces-successful-fracking-in-ukraine-3324>

19 Stevens, P. (2010). The 'Shale Gas Revolution': Hype and Reality. Chathamhouse. September 2010.

20 Barysch, K. (2010). Shale gas and energy security of the EU. Нефтегазовая Вертикаль, 18.

21 Halliburton (2008). US shale gas: an unconventional resource. Unconventional challenges. White paper. Available at [http://www.halliburton.com/public/solutions/contents/Shale/related\\_docs/H063771.pdf](http://www.halliburton.com/public/solutions/contents/Shale/related_docs/H063771.pdf)

22 <http://www.sjrwmd.com/watersupply/droughtproofwell.html>

# Shale gas and hydraulic fracturing: the issues explained

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*In various European countries, discussions have taken place on the issue of whether the development of shale gas should be encouraged or not allowed. The debate mainly relates to the hydraulic fracturing technology to make shale gas wells producing economically viable amounts of gas. However, many people are still puzzled about what exactly hydraulic fracturing entails and how severe the environmental issues can be. This article tries to explain the technology and shed some light on the environmental issues.*

## Introduction

Shale gas has been produced in small quantities for decades. However, because of the low productivity and relative high production costs shale gas production has never attracted a lot of attention from the major gas companies. More recently, large scale shale gas production has been made possible because of developments in both 'horizontal drilling' and 'hydraulic fracturing' technologies.

Horizontal drilling is a technology to steer a drill bit into a horizontal direction to provide increased wellbore exposure to a shallow reservoir area while allowing for a reduced number of surface locations. Horizontal drilling is a well understood and accepted technology. Figure 1 shows the difference between a horizontal and a vertical well. The other technology, hydraulic fracturing, or 'fracking', is becoming a major point of discussion because of the risks involved concerning ground water contamination and the use of large amounts of water. To understand the need for hydraulic fracturing, first the differences between conventional and unconventional gas production have to be explained. Natural gas is formed by thermal transformation of an organic-rich source rock. With conventional natural gas, the gas migrates upwards until it is trapped in a porous reservoir from which it can be recovered by conventional (i.e. vertical) drilling. Gas production from conventional porous reservoirs has high productivity because the gas can migrate easily through the reservoir to the well bore (Gas Strategies, 2010)

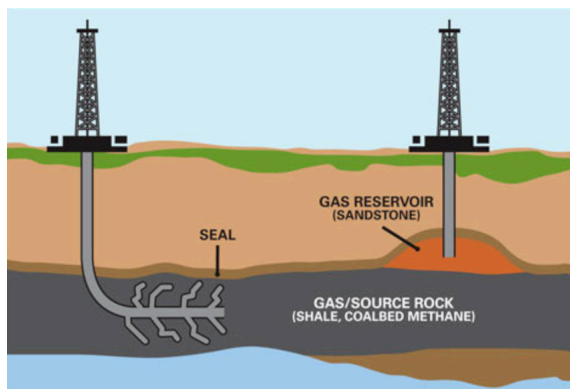


Figure 1: Unconventional versus conventional gas production (DTE Energy, 2011)

Shale gas plays, and other types of unconventional gas plays, are characterized by a source rock with low porosity and permeability where the gas was formed, which in addition acts as the gas containing reservoir. Because of the rock's poor properties (i.e. porosity and permeability), gas doesn't flow to the well bore easily, and therefore requires additional stimulation technologies like hydraulic fracturing.

## What is Hydraulic fracturing?

Hydraulic fracturing is a technique in which a mixture of water, chemicals, and sand are pumped into a well to unlock natural gas or oil trapped in shale formations, by creating cracks (fractures) in the rock and allowing the gas or oil to flow from the shale into the well. When used in conjunction with horizontal drilling, hydraulic fracturing usually enables gas producers to extract shale gas at a reasonable cost. While production of many conventional gas wells have been stimulated using hydraulic fracturing methods, hydraulic fracturing and horizontal drilling is specifically required for shale wells to be productive enough to provide a sufficient financial return (Tyndall Centre, 2011).

The first step in drilling a shale gas well is drilling a vertical well until the depth of the shale deposit, generally two to three kilometres deep (well below usable groundwater aquifers). From here the drilling is redirected in a horizontal direction for about two to five kilometres. Horizontal drilling is necessary because shale gas layers are on average 200 meters thick, and vertical drilling would not provide enough surface contact to economically exploit the well. When the well is drilled and the well casings, required to isolate the overlying zones and to guarantee well integrity, are set, parts of the casing in the horizontal part of the well are perforated to allow the fracturing fluids to come in contact with the shale rock and to start the fracturing process. Next, a large amount of water mixed with sand and chemicals is pumped into the well to increase the pressure above the static level within the rock formation. When this pressure is reached the well gets temporarily plugged to maintain the pressure and achieve maximum fracturing results within the rock. The water pressure opens up extremely small cracks in the rocks, 'fracturing' the rock. The sand is used to fill these cracks or fractures so that they remain open when the pressure is relieved and chemicals are added to assist in the process or to protect the equipment. After the well is sufficiently fractured, the pressure is relieved and the water and chemicals are pumped out. Because of the sand the micro fractures will remain open and the gas can flow to the well more easily and faster resulting in a more economic gas well. Figure 2 shows the different stages in the fracturing process.

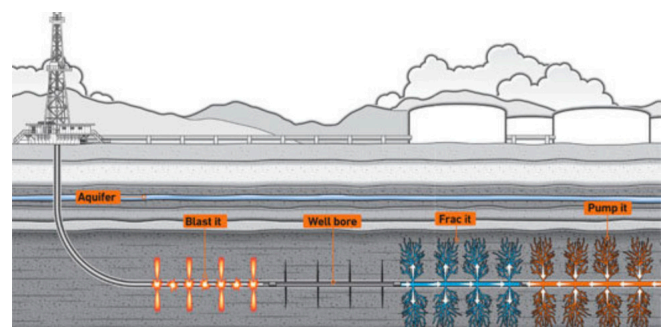


Figure 2: Hydraulic fractured horizontal well (not to scale) (Popular Science, 2011)

### Hydraulic fracturing of shale gas wells

Hydraulic fracturing is often referred to as a technology that has been used for decades in conventional gas production, already starting in the 1940s. However, there are some major differences between the way the technology was used now and in the past.

Hydraulic fracturing as it is now used on shale gas wells was developed in the late 1990s. It is called “slick-water hydraulic fracturing” because it uses a different mix of chemicals than the older methods, reducing the amount of gelling agents and adding friction reducers, making the fluid flow more easily. The modern technology is also known as “high-volume” hydraulic fracturing (HVHF) because it uses much more fluid than the original hydraulic fracturing. With the original fracturing technology, typically 75 to 300 m<sup>3</sup> of fluids were used each time a well was fractured, but HVHF uses on average 20,000 m<sup>3</sup> of fluids, with as much as 30,000 m<sup>3</sup> of fluids to fracture a well, the exact amount depending on the horizontal length of the well bore and the number of fractures created along it (TC Gasmap, 2011).

### Fracturing fluids

Fracture fluids can be based on water, oil, acid, gel, foam and even liquid CO<sub>2</sub>. Most fracturing work is conducted using a water based fluid. In addition, fracture fluids can contain a wide array of additives, each with a particular function, the combination depending on the conditions of the specific well being targeted. For deep shale gas zones, the water is commonly mixed with a friction reducer (called slickwater), biocides, scale inhibitors, and proppants such as sand to hold the fracture open. It is the use of such additives that has raised concerns about hydraulic fracturing, even though overall the concentration of additives in most slickwater fracturing fluids ranges between 0.5% and 2%, with water and sand making up 98% to 99.5% of the slickwater (Oxford Institute for Energy Studies, 2010). Geology dictates the combination of fracturing fluids and proppant used, and part of the challenge of unlocking new plays involves determining the optimal stimulation treatment. Figure 3 shows the typical make-up of a basic fracturing fluid, including the different kinds of chemicals used.

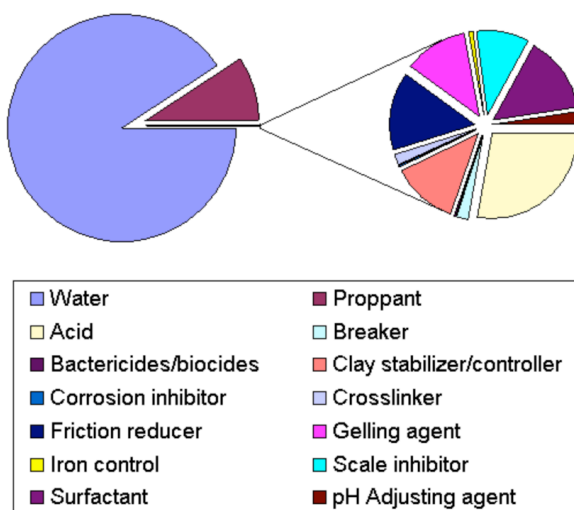


Figure 3: Sample Fracture Fluid Composition  
(NYS Department of Environmental Conservation, 2011)

Even though it is commonly claimed that the chemicals used are common household products they may still have an adverse impact on the environment. For instance, some of the used chemicals are also used in anti-freeze products.

### Environmental impacts of shale gas production

A recent report of the Tyndall Centre (2011) assessed the possible risks and impacts of hydraulic fracturing and shale gas drilling. Some key risks and impacts directly relating to hydraulic fracturing were identified and explained below:

- Groundwater pollution: The potential for contamination of groundwater is a key risk associated with hydraulic fracturing. Commonly used fracturing fluids contain multiple chemical additives, some of which are toxic to humans. Groundwater pollution may occur if there is a catastrophic failure or loss of integrity of the wellbore, or if contaminants can travel from the target fracture through subsurface pathways. The risks of such pollution were seen as minimal from properly constructed wells. However, the risks related to less properly constructed wells are less well documented and may be more significant.
- Surface pollution: While it may not always be possible to pinpoint the exact cause of groundwater contamination, identifying the source for land and surface water pollution is more straightforward. There are a number of potential sources of pollution including: well cuttings and drilling mud; chemical additives for the fracturing liquid; and flowback fluid, the liquid containing toxic chemicals that returns to the surface after fracturing. There are various routes by which these potential sources can cause pollution.
- Water consumption: Hydraulic fracturing requires very significant amounts of water. To carry out all fracturing operations on a six well pad takes between some 50 and 170 thousand cubic metres of water. For the annual production of 5 bcm of shale gas over 20 years this would boil down to an average annual water demand of 700-3000 thousand cubic metres.
- Disposal of flowback fluids: After a shale gas well is fractured, between 25 and 80% of the fluids will return to the surface before and during gas production. These fluids still contain most of the chemicals initially used, as well as heavy metals and radioactive elements from the fractured layers. Treating or disposing of these fluids is expensive, and if not done properly they can contaminate surface or drinking water.
- Seismic events: Seismic events, or earthquakes, have in some instances been reported to be caused by hydraulic fracturing (Daly, 2011). Examples of earthquakes after hydraulic fracturing are small seismic events in the UK (Vukmanovic, 2011), and a strong rise in seismic events in Oklahoma, where a lot of fracturing has been performed (Daly, 2011). However, these are only small events, and have always been part of natural gas production and other sub surface industries.

The above risks directly associated with hydraulic fracturing are not the only issues related to shale gas production, particularly when considering relatively densely populated areas such as northwest Europe. More ‘run of the mill’ impacts such as vehicle movements, landscape and noise pollution may also be of significant concern locally, especially when considering the scale of development required to deliver significant supplies.

### Technological developments

Because of tightening regulations and growing public awareness of the risks of hydraulic fracturing, the industry is working on better and cleaner processes for hydraulic fracturing. However, not all of the issues are easily solved, especially not those relating to the scale of the industry. The new developments at this moment are mainly focused on limiting the use of water and toxic chemicals. Limiting the use of water can be done by:

- Better wastewater treatment and reuse, making it possible to use the same water for multiple fracturing stages, and decreasing the net amount of required water;

- Using a foam as part of the fracturing fluid, potentially reducing the required amount of water with up to 95% (Gies, 2011);
- Using liquefied propane gas (LPG) instead of water, which is actually a thick gel. The gel purportedly turns to vapour underground, then returns to the surface with the gas where it can be collected and possibly reused (Gies, 2011).

For limiting the use of toxic chemicals, the fracturing companies search for information about offshore fracturing fluids, which are not allowed to be toxic to marine life, and so do not contain any toxic chemicals (Earthworks, 2011). Of course, all of these measures will come at a cost, making drilling more expensive.

## Conclusion

Like every energy source, shale gas has its drawbacks. The process involves injecting large amounts of water and chemicals deep underground. If done right, this should not contaminate freshwater supplies or cause other environmental problems. Rogue companies, however, have cut corners in the past, causing environmental problems and contributing to increased controversy surrounding fracturing. The problems relating to hydraulic fracturing are real, but according to a variety of sources do not seem to be insurmountable. For instance, an exhaustive study from the Massachusetts Institute of Technology concluded, "With 20,000 shale wells drilled in the last 10 years, the environmental record of shale-gas development is for the most part a good one" (Brooks, 2011).

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# The Regulatory Framework for Hydraulic Fracturing in Texas

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***The ability to economically produce natural gas from unconventional shale gas reservoirs has been made possible recently through the application of horizontal drilling and hydraulic fracturing. Texas is a major player in these developments. Of the eight states and coastal areas that account for the bulk of U.S. gas, Texas has the largest proved reserves.***

Texas' Barnett Shale already produces six percent of the continental U.S. gas and exploration of Texas' other shale gas regions is just beginning. Shale gas production is highly controversial, in part because of environmental concerns. This paper explores the regulatory framework for hydraulic fracturing of shale gas plays in Texas.

In its 2011 Annual Energy Outlook, the U.S. Energy Information Administration (EIA) estimates that the recoverable gas resources from U.S. shale gas plays have more than doubled in the past year, in large part due to the successful use of advanced drilling techniques. Indeed, the report forecasts that by 2035 almost half (45 percent) of the natural gas produced in the U.S. will come from shale gas, up from 14 percent in 2009 (Energy Information Administration, 2011). Over the last few years new drilling techniques are remapping the energy future of the U.S. These new drilling techniques have opened vast quantities of natural gas. Estimates suggest these new reserves will amount to 616 trillion cubic feet (17,248 billion cubic meters) -- about the same as Kuwait's proven reserves (Cox, 2010).

While conventional sources of natural gas are declining, unconventional sources like shale gas are rapidly increasing. Instead of facing dwindling reserves of conventional natural gas, the application of horizontal drilling and hydraulic fracturing (HF or fracking) techniques in shale gas reservoirs has turned the U.S. from a nation of waning gas production to one of increasing production. Texas is forecast to be a key state contributing to U.S. natural gas supplies in the future.

The use of fracking and the gas drilling boom that has resulted from its use has led, however, to some controversy and environmental worries. Concern centers not only around air emissions and potential water contamination associated with fracking chemicals used, but also around the substantial amount of water necessary to make the wells productive. Additionally, apprehension extends to chemical waste management practices, the large land footprint of drilling operations, and the necessary infrastructure required to support these large drilling operations.

## ***Why Texas Matters***

The state of Texas contains five major shale gas plays and has assumed a critical role in demonstrating the new HF drilling technology. The largest of the Texas' plays, the Barnett play, is located in north central Texas. Nationally, this was the first play to be exploited. Between 2005 and 2007, almost all completed horizontal HF wells were successful in the Barnett Shale play. Texas is also site of the Haynesville Shale play in the eastern part of the state along the Texas-Louisiana border. This site is expected to be the largest national producer over the coming decade. The Eagle Ford Shale play, located just south of San Antonio, is the newest site to begin production and is also expected to be a significant producer. Texas also is home to the Barnett-Woodford Shale in the west

and the Bend Shale play in the Panhandle.

Production of shale gas in Texas is increasing rapidly. In 2007, Texas produced 988 billion cubic feet (27.66 billion cubic meters) of shale gas. In 2009, production rose to 1,789 billion cubic feet (50 billion cubic meters). That production accounted for 57 percent of the 3,110 billion cubic feet (87 billion cubic meters) of shale gas produced in the United States that year (Energy Information Administration, 2010). Estimates of proved shale gas reserves within Texas continue to rise at the same steep rate.

## ***The Regulatory Tangle of Texas***

While other states have moved legislatively or administratively to control shale gas drilling within their jurisdictions, the regulatory climate of Texas has thus far prevented any similar action in the Lone Star State. Where some efforts have been attempted, they have not gone far. The reasons are interrelated and primarily due to the fragmentation of the regulatory bureaucracy, a fundamental anti-regulatory disposition, and a well-entrenched legal and administrative structure that promotes oil and gas extraction above other concerns.

In Texas, multiple commissions and authorities have a role to play in jurisdiction over mineral, water, air, and land regulation. But unlike states like California, that also have a fragmented structure, Texas does not have a strong ethos of environmental protectionism. Moreover, under the leadership of Governor Rick Perry, Texas has taken a decidedly anti-EPA and anti-federal regulation position.

Within Texas, environmental pollution issues typically fall under the jurisdiction of the Texas Commission on Environmental Quality. TCEQ is the agency that deals with air and water quality issues as the state agency given primacy for implementing federal clean water and air laws. TCEQ, however, has recently found itself in conflict with the EPA over what EPA considers lax enforcement of the federal Clean Air Act. In a most unusual step, in March of 2010, EPA disapproved Texas' air permitting exemption program (Environmental Protection Agency, 2010a). The Qualified Facilities exemption rule was submitted by TCEQ to EPA as part of the required State Implementation Plan (SIP). The rule allows certain facilities that have Texas permits to avoid following federal Clean Air Act requirements. EPA rejected the permitting plan and told Texas to change the SIP to bring it into compliance with Clean Air Act requirements (Galbraith, 2010). Texas refused and the standoff began. The Governor and the TCEQ argue that the federal government is meddling in Texas' business and is involved in an unconstitutional overreach.

Tension between the TCEQ and the EPA escalated later in 2010 when Texas became the only state to refuse to implement EPA's greenhouse gas regulations. While several other U.S. states have joined with Texas in suing the EPA over its efforts to regulate greenhouse gases, Texas is the only state that has refused to create a state program to implement the federal rules. In December, EPA announced that it would seize authority and issue Clean Air Act greenhouse gas permits in Texas because of Texas' unwillingness to do so (Michaels, 2010). Texas appealed to the courts and continued to fight the EPA but as of November 2011, EPA began issuing greenhouse gas permits for Texas.

EPA has pushed TCEQ to consider air emissions in the Barnett Shale. Responding to complaints from citizens of Dish, Texas EPA began an investigation of toxic air emissions in 2010. The TCEQ also conducted a study of air quality in the Barnett Shale. They found elevated levels of benzene and other chemicals. TCEQ recommended long-term monitoring (Vaughan and Pursell, 2010). Subsequently, the TCEQ put in place a

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two-phase monitoring study to examine air emissions in the Barnett Shale (Texas Commission on Environmental Quality, 2010). But drilling continues.

Conflict with the EPA has spilled over to another Texas agency, the Texas Railroad Commission. Under Texas law, the Railroad Commission (RRC) regulates the oil and gas industry including pipeline transporters. It is responsible for community safety and stewardship of natural resources, while at the same time one of its missions is to promote “enhanced development and economic vitality” (Railroad Commission of Texas, 2011a). Given its dual purposes, some would suggest that the missions of community safety and of stewardship of natural resources fall victim to that of promoting the oil and gas industry.

The RRC has come into conflict with the EPA for its lax enforcement of the Safe Drinking Water Act. In December of 2010, EPA issued an Imminent and Substantial Endangerment Order to protect drinking water in Southern Parker County. By this order the EPA ordered a natural gas company operating in the Barnett Shale to take immediate action to protect the water wells of local residents. EPA testing confirmed the presence of flammable substances in the drinking water. By issuing this order, the EPA trumped the RRC which had done nothing in response to complaints from homeowners (Environmental Protection Agency, 2010b).

Air and water quality issues are not the only regulatory concerns in Texas. In an arid state like Texas, water quantity is a key issue. When it comes to determining adequacy of water supplies, multiple authorities exercise overlapping jurisdiction. These include the more than three dozen river authorities and special law districts, multiple aquifer authorities, nearly 100 Groundwater Conservation Districts, sixteen Groundwater Management Areas, and seven Priority Groundwater Management Areas, myriad water utilities, municipalities, and counties. In addition, the Texas Water Development Board and its regional planning committees are responsible for producing a 50 year plan for water resources, updated every 5 years. However, when it comes to use of groundwater use for drilling gas or oil wells, these regulatory bodies have no authority.

The RRC allows a company to use as much groundwater as it needs to complete a well (Railroad Commission of Texas, 2011b). Drillers that wish to use surface water do need to apply to TCEQ for a permit. The first such application was filed in 2010 for use of San Antonio River water for a fracking operation in the Eagle Ford Shale. The permit seeks 65 million gallons a year for ten years (Harman, 2010). The use of such vast amounts of water raises some concerns especially in dryer parts of the state but thus far there are few attempts to control the water use. Groundwater is specifically exempted from control under the state’s water code.

In Texas, surface land property rights can be separated from mineral rights and mineral rights supersede property rights. Natural gas is classified as a mineral. The separation of surface rights from mineral rights can happen in several ways. Either the landowner sells the minerals but retains the surface or the landowner retains the minerals but sells the surface. In Texas, the latter is more common. The language regarding the terms of the sale is recorded on the deed. If the seller fails to reserve the minerals when selling the surface, the mineral ownership goes automatically to the buyer and the transaction is considered a fee simple estate. Whether the surface and mineral estates are separated on a tract of land or not, in Texas mineral rights are dominant. This is because to benefit from the ownership of minerals, access to the surface of the land is essential. If mineral ownership did not have priority over surface rights in law, then mineral rights would be worthless for the mineral owner could not enter the land to explore and extract the minerals (Fambrough, 2009).

Because the surface of the land must be disturbed so that minerals may be accessed, this can create a tension between surface land property owners and mineral rights owners. It is important to note that often the same individual owns both the surface and mineral rights, in which case

no conflict would ensue. Mineral rights owners are permitted by Texas law to lease the rights to explore for oil and gas to a company which in turn must provide the surface land owner a notification of intent to explore and drill. In Texas, though, the surface land owner cannot block the mineral rights owner from access to the minerals. Mineral rights owners can use as much surface land as is reasonably necessary to explore, drill, and extract minerals. The mineral rights owner is allowed by Texas law to clear trees and remove fences so that drilling rigs can be brought to the property. Once gas is discovered, the mineral owner can bring in extraction equipment on a dedicated pad that can be an acre or more in size. The mineral rights owner or lessee may also erect pipelines for the removal of minerals. Texas law does not require the mineral owner or lessee to pay for damages to the land or to pay reparations for the loss of use of the land while the drilling operation is in place (Woods, 2010).

In Texas, private gas pipeline companies have been given the right of eminent domain by state statute, which in practicality allows them to lay lines where ever they choose. That interstate pipeline companies have the power of eminent domain is established in federal law. Interstate natural gas transmission pipeline companies were given the power of eminent domain by the federal Natural Gas Act of 1938. An interstate pipeline company may use the power of eminent domain if the Federal Energy Regulatory Commission (FERC) has issued a certificate of public convenience and necessity for a pipeline project and the company has not been able to successfully negotiate a purchase price with the property owner (Arntsen and Simmons, 2009). Intrastate pipelines are generally regulated by state Public Utility Commissions. States vary on the authority given to intrastate pipeline operators. In most states, intrastate pipelines and gathering pipelines -- lines that take the gas from the wells to a larger transmission line -- do not have eminent domain authority (Killion, 2010). In Texas, however, pipeline companies have considerable sway.

In Texas, pipeline operators and gas utilities have the power of eminent domain. The Railroad Commission does not have any right to regulate any pipeline with respect to the exercise of eminent domain (Railroad Commission of Texas, 2010). If a company wants to cross private property to lay a pipeline, they are allowed to do so. If they take the entire property through condemnation, they were required under the 1936 case *State v. Carpenter* to provide fair market value for the land (Brannan and Peacock, 2010). However, in 2004, the Texas Supreme Court ruled in *Hubenak v. San Jacinto Gas Transmission Co.* that the dollar amount of the condemning agent’s offer does not have to align with fair market value for the land. Further, even if the party whose land is being taken wins in a court appeal, the attorney fees and appraiser fees cannot be recovered as part of the judgment (Fambrough, 2010). These aspects of Texas policy make opposing mineral development difficult and costly.

## Conclusion

Taken together these provisions and actions constitute a very friendly environment for oil and gas producers in the state of Texas. Unlike actions in other states and at the federal level to control horizontal drilling and hydraulic fracturing, Texas remains pretty much “the wild West.” The fragmentation of the Texas regulatory bureaucracy, a fundamental anti-regulatory disposition of the TCEQ and the Governor, and the well-entrenched legal and administrative structures that promote oil and gas extraction above other concerns make Texas a strong pro-drilling state. While land owners who lease their mineral rights to oil and gas companies stand to gain significant income from such leases, once the lease is negotiated landowners have few protections. How much water will be used, the disposal of wastewater, and the footprint of drilling operations are not under their control. What will remain of the rural land that passes to future generations is unclear. And urban dwellers who find themselves unexpectedly living in a gas field will have to deal with the development and production.

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# The Economic Impacts of Shale Gas Extraction: Moving Beyond Jobs and Tax Revenues

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*After decades of speculation, recent advances in drilling technologies coupled with high prices for natural gas have made it economical to extract natural gas from shale rock formations deep below the surface of the earth. The process, which involves horizontal drilling and the hydraulic fracturing of shale rock, requires the construction of drilling pads, large quantities of water to fracture the shale rock, and methods for treating or disposing the water that returns to the surface.*

Because such unconventional gas reserves often lie below regions previously familiar to the energy industry, and because potential threats to the natural environment are not well understood, policy makers face large uncertainties over how best to prepare for and regulate the industry. Responses have varied dramatically within the United States. The governments in Texas and Arkansas, states already familiar with the conventional (shallow well) gas extraction industry, largely relied upon existing regulations. But in the state of New York, where the gas industry traditionally has had little activity, a moratorium on unconventional gas extraction was enacted until more could be learned.

Of particular interest to policy makers in all regions are the expected economic benefits associated with the new industry. Job creation, state tax revenue earnings, and overall economic growth typically top the list of economic impacts of interest. The Economic Impact Report is a particularly useful tool for estimating these impacts, and the gas industry often funds the research behind these reports. But the Economic Impact Report involves several layers of subjective decision making, overlooks a host of other relevant economic impacts, and is based on a core economic theory that may not be appropriate in all cases. This article explains how the Economic Impact Report is generated, discusses some of the weaknesses of the practice, and then introduces some of the other known economic consequences of unconventional gas extraction that could prove important to policy makers.

## **The Economic Impact Report**

Many policymakers, private consultants, and academic and professional economists are familiar with the Economic Impact Report. These reports estimate the jobs, gross revenues, and tax revenues associated with the economic activity of a single firm, a single institution, or any particular industry. Economic impacts result from the direct, indirect, and induced economic activity associated with the firm, institution, or industry. Direct economic effects are estimated by simply examining the financial statements of the firm or industry. All revenues earned, jobs created, and taxed paid are said to have a direct effect on the economy. Indirect economic effects occur when the firm or industry purchases supplies, raw materials, and labor resources from other firms in the economy. This spending indirectly contributes to the jobs, revenues, and taxes paid by these other firms. Induced effects arise after incomes earned from the beneficiaries of the indirect spending are then spent again and again throughout the economy. These induced effects are estimated using

multipliers generated from any number of input-output models created by professional economists.

A number of Economic Impact Reports have been produced to estimate the economic benefits of unconventional gas extraction in the United States.<sup>1</sup> The intended audiences of these reports are often local and regional policy makers. If policy makers can be convinced that the new industry will generate sufficient increases in jobs, tax receipts, and economic growth, then those policy makers may be less likely to implement safety and environmental regulations. Also, because these impact reports can specify the economic benefits within any defined state or region, they especially match the political interests of many state policy makers.

That direct, indirect, and induced spending might generate broad economic prosperity originated with the theories of the British economist John Maynard Keynes in the 1930's. Keynesian economic theory is most appropriate for understanding economies operating below capacity when economic resources are underemployed, such as during the Great Depression and during the present ongoing recession. Although Keynesian economic theory is an important part of the curriculum at many colleges and universities across the globe and remains important to both modern empirical and theoretical research, academic research economists have abandoned the practice of writing Economic Impact Reports. Such reports are no longer considered economic research suitable for publication in the academic journals. Instead private consulting companies and academic economists looking to make a few consulting dollars on the side author Economic Impact Reports for clients in industry and government.

One reason for the lack of interest from professional research economists for the Economic Impact Report is the high level of subjectivity inherent to the practice. For example, important to the estimate of the indirect effects to any specific region is determining the portion of a firm or institution's overall spending on resources from local, rather than non local suppliers. The purchase of an imported automobile from a local car dealership will likely have a different economic impact than the purchase of a domestic automobile from the same dealership. But the economist might only be given the zip code of the car dealership when determining whether a purchase is local or not and is therefore unable to distinguish between these two purchases. With thousands of purchases per year, the process of identifying truly local suppliers may become impossible. Also, once the indirect spending from local vendors is "estimated", then the induced effects are estimated by selecting an appropriate spending multiplier from several possibilities with little guidance over which multiplier is most appropriate. Finally, the output of the Economic Impact Report assumes no crowding out – all economic resources employed to support the firm or industry's spending are otherwise idle and therefore not reallocated from other sectors of the economy. This last assumption may only be appropriate in an economy awash with unemployed economic resources. In combination, these sources of subjectivity allow the economist substantial leeway when completing an Economic Impact Report, reduce the process from a science to perhaps an art, and result in the repeated use of the word "conservative" in the report to attempt to convince the reader that wherever judgments were made, options were pursued that minimized the economic impacts.

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<sup>1</sup>For a detailed review of these reports, see "The Economic Impact of Shale Gas Extraction: A Review of Existing Studies," published in *Ecological Economics* 70(7), May 2011, 1243-1249.

But perhaps the most disappointing aspect of traditional Economic Impact Statement involves what is omitted. First, who wins and who loses? A new industry may drive some existing firms and industries out of the economy while others may emerge. These details are usually of interest, but Economic Impact Reports by design suggest everyone will benefit from the extra spending. Second, the sustainability of the estimated economic impacts is ignored. Will the economic benefits be short lived or long lasting? Third, the economic impact report fails to consider the national and international benefits and costs that may originate from a firm, institution, or industry. The remainder of this article attempts to address these additional questions. Data from the United States Economic Census are summarized in the next section to see what effect the maturing industry has had on the state and local economy. Have the benefits touted by the Economic Impact Reports been realized? A description of the specific winners and losers, as identified in the economics literature, is then provided in the section that follows further below. The final section then summarizes the broad benefits and costs to the national and global economies stemming from this industry.

### ***Moving Beyond the Economic Impact Report***

Rather than relying upon spending forecasts to understand the economic impacts of the unconventional gas industry, Table 1 summarizes observed economic variables both before and after the initiation of the industry in U.S. states both with and without the industry. All data are obtained from the United States Economic Census, which is taken every five years. Two time periods are reported. The first time period, from 1997-2002, predates almost all unconventional gas activity in the United States. The second time period, 2002-2007, featured significant mining activity in both the Barnett shale play in Texas and the Fayetteville shale play in Arkansas. The limited data points are woefully insufficient for making any statistical inference about the overall economic impact of the industry. But if the industry is responsible for sizeable economic gains, then these data should recover something. Extraction from the Fayetteville shale play in Arkansas began in 2002. Prior to 2002, employment in the mining sector of the economy grew by an average annual rate of 4.52% in the state of Arkansas (the first row of Table 1). Gross revenues to mining companies grew by an averaged annual rate of 3.12%. Both of these measures increased sharply in the five years between 2002 and 2007. Employment in the mining industry grew by an average annual rate of 13.59% and gross revenues to the mining industry grew on average by almost 40% per year. This rapid increase in average growth rates within the mining sector also emerges in Texas, site of the Barnett shale play since 2001. At question is the extent to which this rapid growth within the mining industry extends to the broader state economies. Table 1 also has the pre- and post-2002 average employment and gross revenue growth rates for the states of Arkansas and Texas. Similar data are also obtained for the states of New Mexico and Tennessee, two south-central states adjacent to Texas and Arkansas but not served by the unconventional gas extraction industry. The average annual growth rate of employment decreased in both Arkansas and Texas after 2002, as was the case in New Mexico. Unobserved macroeconomic variables are likely the reason. But if the decreases observed in Arkansas and Texas are less severe than the decreases in Tennessee and New Mexico, then the new unconventional gas industry could be responsible for relative gains in economic performance. Using the differences in differences approach, the economies of Texas and Arkansas together experienced a 0.97 point decrease in the average growth rate in employment. Tennessee and New Mexico experienced an averaged 1.78 point decrease. If no other economic variables affected these latter two economies any differently than the economies of Texas and Arkansas, then we can conclude that the unconventional gas industry was responsible for an annual 0.8 point increase in the growth

rate of employment between 2002 and 2007. The Arkansas economy employed 926,150 workers in 2002, thus the 0.8 percent annual increase suggests the addition of 7,409 jobs per year created by the unconventional gas industry during the 2002 to 2007 period. The Economic Impact Report for the state of Arkansas (published by the Center for Business and Economic Research of the University of Arkansas) predicted the addition of 9,533 jobs in Arkansas. In terms of gross revenues, the differences in differences approach suggests that gross revenues in Texas and Arkansas grew at an average rate that exceeded that in Tennessee and New Mexico by 3.25%.

**Table 1: A Comparison of State Economic Indicators**

Location	1997-2002	2002-2007
Arkansas - Mining Industry Fayetteville Shale (Began 2002)	Employment: 4.52% Revenues: 3.12%	Employment: 13.59% Revenues: 38.98%
Texas - Mining Industry Barnett Shale (began 2001)	Employment: 1.52% Revenues: 4.17%	Employment: 17.28% Revenues: 20.45%
Arkansas - All Industries Fayetteville Shale (Began 2002)	Employment: 1.16% Revenues: 2.18%	Employment: 0.97% Revenues: 9.41%
Texas - All Industries Barnett Shale (began 2001)	Employment: 4.41% Revenues: 2.52%	Employment: 2.67% Revenues: 12.51%
New Mexico - All Industries No Shale Activity	Employment: 6.21% Revenues: 3.46%	Employment: 2.61% Revenues: 11.00%
Tennessee - All Industries No Shale Activity	Employment: 1.13% Revenues: 3.07%	Employment: 1.18% Revenues: 6.25%

Employment and gross revenue data are also obtained for specific counties within Texas and Arkansas, and are reported in Table 2. Within Arkansas, unconventional gas extraction from the Fayetteville shale play occurs in both Faulkner and White counties but not in Garland or Saline counties. The differences and differences approach when applied to these two sets of counties suggests the average growth rate in employment decreased by 4.98% in the shale counties and decreased by only 0.99% in the non-shale counties – contradicting the results based on statewide data given above. These data suggest the unconventional gas industry is responsible for a 3.99 point decrease in the employment growth rate in these two counties. A decrease of 0.27 points is estimated using counties in Texas. A comparison of the growth rates of gross revenues suggests shale counties in Texas and Arkansas also experienced lower growth in gross revenues than counties without shale. Thus, the data suggest that state economies grow but local (county-wide) economies suffer from the unconventional gas industry. But problems are associated with these conclusions. First, unobserved economic variables may have affected the shale states and counties in ways that differ from how they affected the non shale states and counties – the appearance of the shale gas industry may not be the only difference between these sets of states and counties. Statistical techniques could be utilized to control for these other variables, but such techniques require larger data sets than are reported in Tables 1 and 2. And because the industry is rather new, such data are not yet available. Thus, the actual impact the industry is having on the local and state economies remains largely unknown.

### ***Specific Economic Impacts Associated with Unconventional Gas Extraction***

Moving beyond the impact on aggregate economic performance, the remainder of this essay summarizes what we have learned about the specific economic impacts within various sectors of the economy. The literature is admittedly thin at this point as post-industry data are only

**Table 2: A Comparison of County Economic Indicators**

Location	1997-2002	2002-2007
Faulkner, AR - All Industries	Employment: 6.63%	Employment: 2.13%
Fayetteville Shale (Began 2002)	Revenues: 4.49%	Revenues: 5.67%
White, AR - All Industries	Employment: 4.82%	Employment: -0.63%
Fayetteville Shale (Began 2002)	Revenues: 5.86%	Revenues: 3.33%
Garland, AR - All Industries	Employment: 0.58%	Employment: -0.95%
No Shale Activity	Revenues: 1.73%	Revenues: -0.23%
Saline, AR - All Industries	Employment: 0.78%	Employment: 0.34%
No Shale Activity	Revenues: 0.53%	Revenues: 0.37%
Denton, TX - All Industries	Employment: 5.44%	Employment: 5.03%
Barnett Shale (began 2001)	Revenues: 15.56%	Revenues: -1.32%
McLennon, TX - All Industries	Employment: 0.49%	Employment: 0.35%
No Shale Activity	Revenues: 7.64%	Revenues: -1.39%

now becoming available to researchers. The most thorough examination of the economic impacts of the industry is performed by Susan Christopherson of Cornell University. The full report is available at <http://www.greenchoices.cornell.edu/development/marcellus/>. Some of these results are summarized below.

### ***Economic Effects on Landowners***

The majority of unconventional gas reserves lie below privately owned rural property. In order to access these natural gas sources, mining companies must first gain permission from the surface land owners. The typical contract includes both a lease agreement and future royalty payments. The lease agreement stipulates a monthly amount paid to the landowner for permission to construct a mining pad and access road. Royalties are then paid on each unit of natural gas extracted at the site. These lease and royalty agreements are usually kept confidential in the short run. Thus, neighboring property owners can negotiate very different terms. Lease payments have ranged substantially between just \$50 to as much as \$7,000 per acre per year. Royalty agreements have varied between 12% and 21%. Although the process yields a few overnight millionaires, the average landowner receives a few thousand dollars per year. Furthermore, a well pad on a property has been estimated to reduce the value of the property by 8.67% in Garfield County, Colorado. Apparently prospective land buyers are unimpressed by the mining activity on the property. Neighboring landowners whose surface property may not be conducive to drilling due perhaps to inadequate size, severe land grade, or flood plain issues must experience the nuisance of drilling on neighboring properties without gaining lease or royalty revenues. Although economic studies estimating these external costs have not materialized in the literature, studies estimate that each well pad involves an estimated 890 to 1,340 truck trips. Related economics literature has estimated that vehicular traffic negatively affects adjacent property values.

### ***Economic Impact on Housing***

The unconventional gas mining industry typically imports trained labor from other regions of the country. Short-term housing demand therefore increases sharply. Rents have been estimated to increase by 60% in the short run in some rural areas. Vacancy rates plummet, and many low-income residents are displaced by the industry. These effects are most noticeable in medium sized municipalities large enough to be attractive to the imported labor force but not large enough to offer sufficient quantities of housing.

At question is how long the increase in housing demand will persist. Studies of housing values suggest a boom/bust cycle may accompany the industry. Once well drilling and pipe line construction has been completed in any specific area, the imported labor force migrates to another region. Experiences suggest this cycle takes about 6 years to complete. For example, in Grand Junction, Colorado, vacancy rates decreased from 10% in 2004 to 2% in 2008 with the emergence of the unconventional gas industry. But vacancy rates then increased back to 10% between 2008 and 2010. The same pattern emerged in Glenwood Springs, Colorado as vacancy rates decreased from 6% to 1% but then back to 4% over the same time frame. No such cycle exists in state-wide data for Colorado.

Housing prices followed this same pattern. Again in Grand Junction, Colorado, housing prices traditionally grew at about the state average of 2% per year. With the emergence of the unconventional gas industry, housing prices began to grow by 10% more than the state average between 2003 and 2008. But since 2008, housing prices decreased by double digit percentage rates even as the state average held steady. These observations suggest the increased demand for housing associated with unconventional gas extraction is short lived.

### ***Impact on Public Services***

The emergence of the unconventional gas industry in rural regions of the country can put unexpected pressures on public services. Many municipalities can absorb rates of population growth of up to about 6% to 7%. Systematic institutional breakdowns occur with population growth rates of 15%, a rate that can accompany the new industry. Health and education systems, road maintenance, emergency services, social services, public administration services, and environmental monitoring services are most sensitive to the emerging industry.

### ***Impact on Local Labor Markets***

Most new employment opportunities for the local labor force associated with the unconventional gas industry are in trucking. Aggregate materials for pad development, tools and supplies for drilling, and pipeline construction materials require the use of trucks. Once the drilling begins, trucks are needed to transport water and drill casing materials. Trucks are also necessary for transporting earth and waste water for proper disposal (in some cases over long distances). The demand for trucking is so intense in some areas that other industries relying on trucking services are affected. The dairy industry is particularly crowded out in many rural regions. Other local employment opportunities associated with the unconventional gas industry are in food service and hotel/motel accommodations.

But the high-skilled well-paying jobs are usually reserved for imported labor forces that have developed long lasting relationships with the mining company. These workers construct the well pads, construct the pipelines, operate the drilling process, and capture the gas. Although local labor forces could be trained to fill some of these jobs, the transitory nature of the industry would eventually take local employees to other parts of the country once they become skilled in the industry – a form of brain drain that might likely result from any investment in the local labor force.

### ***Crowding Out***

The impact on the dairy industry mentioned above is one form of economic crowding out that can occur with the emergence of the unconventional gas industry. Crowding out can also be associated with land used by the industry. First, farm production has been shown to decrease as local farmers cash out after agreeing to a long term lease and royalty contract. The result is less food production. Empirical evidence in Pennsylvania also suggests speculative landowners are less likely to convert agricultural land to housing subdivisions if gas extraction may occur in the region. Instead the land is preserved for possible use by the extraction industry. Thus, the local home construction industry may be

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affected. Evidence also suggests that tourism decreases with the emergence of the industry. Not only are overnight accommodations difficult to find, but the replacement of natural vistas with a patchwork of drilling pads, access roads, and pipelines makes the region less suitable for fishing, hunting, camping, and hiking. The drop in tourism dollars is most acute in rural counties.

### ***A Broader Perspective on Economic Impact***

From a national or global perspective, the benefits and costs associated with the unconventional gas extraction industry appear very different than at the local perspective. Local jobs and tax revenues play no role. At question is whether the value society places on the gas itself exceeds the private and external costs of extraction. If gas is valued, perhaps because the winter is cold or other fuels are not available, then the benefits of

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extraction are large. If the extraction process is resource intensive or if environmental spillovers are substantial, then the social costs may exceed the benefits. Damage to roads and infrastructure, nuisance to neighbors, cyclical economic upheaval, and climate consequences of adding fossil fuels contribute to the external costs. External benefits accrue if the extracted natural gas replaces other fossil fuels with large environmental costs.

If the industry internalized all of these benefits and costs, then profit maximizing decisions of extractors are consistent with maximizing societal net benefits. A severance tax set equal to all marginal external costs minus all external benefits will allow for such internalization. Mining companies willing to pay the tax in addition to the private extraction costs extract gas only if that gas generates net gain to society.

## Developments in the green gas sector

Steven von Eije

Energy Analyst, Energy Delta Institute

*This section of the Quarterly is fully dedicated to green gas. We made this choice because there are currently many interesting developments in the green gas sector. Even though green gas only has a very marginal contribution to the overall energy supply in the Netherlands (around 30 million m<sup>3</sup>), this share is expected to increase significantly in the future.*

On the 6th of 2011 September Green Gas Netherlands foundation (GGNL) was launched to increase the production volume of green gas. They intend to do this by pooling knowledge and practical experience and to use this combination to help accelerate developments in the green gas sector. In addition they stimulate new projects and will propose solutions to existing bottlenecks. GGNL has an ambitious target of multiplying the total production volume of green gas by ten, from the current 30 to 300 million m<sup>3</sup> (mcm). Between 2014 and 2025 they intend to multiply production tenfold again, from 300 mcm to 3 billion m<sup>3</sup>.



Figure 1: Maxime Verhagen (minister of EL&I) and Ulco Vermeulen (Chairman GGNL), source: GGNL <sup>1</sup>

This year's Dutch stimulation grants for sustainable energy production (SDE+) also favoured green gas production. Of the total available budget of €1.5 billion, initially 50% was available for green gas production. Within several days the entire SDE+ budget had been requested by aspiring renewable energy producers. Since the system favoured the cheapest sustainable energy generation production, far more aspiring green gas producers requested subsidy than aspiring renewable electricity producers and more than two thirds of the requests

were submitted by aspiring green gas producers. Based on these requests, the minister responsible for the SDE+, Maxime Verhagen, decided to change the amounts available for green gas and green electricity. Of the total budget, two thirds is now available for green gas production.

Unfortunately, green gas production is still far more expensive than the production of natural gas. While natural gas was traded at an average of €0.199<sup>2</sup> in 2010, green gas produced by co-digestion still costs around €0.62 per m<sup>3</sup>. In order to significantly increase green gas production, the production costs will have to decrease. Several developments are underway with the aim of lowering the production costs of green gas and some of them deserve to be highlighted here.

### Green gas hubs

In the Netherlands several initiatives are underway to exploit the potential economies of scale in upgrading biogas to natural gas quality (it is then called green gas), and this is accomplished by building so called "green gas hubs". The first certified green gas hub is located in Tilburg<sup>3</sup> where Attero produces biogas from a landfill which is then upgraded to green gas. In addition, the biogas from a nearby wastewater treatment facility is upgraded at this location. In total 7 initiatives are underway in the Netherlands to create green gas hubs. In the contribution of Kirsten van Gorkum, biogas hubs are described in more detail (See "Green gas injection in practice from a regional grid operator point of view").

### Decision Support Tool for investments in the gas distribution system

In order to accommodate green gas in the existing natural gas grid many investments are necessary. Investments vary from green gas hubs, biogas transport pipelines, connection to either the distribution or transport grid for natural gas, and associated compression capacity. The optimal choice, both from a CO<sub>2</sub> and financial viewpoint, differ per situation. Taede Weijdenaar, a PhD student from the University of Twente is currently working on a decision support tool to aid in this decision-making process. This tool is described in "Development of a Decision Support Tool for Investments in the Gas Distribution System."

### Valorisation of manure

The Netherlands is currently importing a large amount of feed for livestock, and the minerals present in the feed that is imported remain in the manure the animals produce. If this manure is used to produce biogas, these substances remain in the digestate. Both manure and digestate present a problem to Dutch farmers, since they are only allowed to apply a limited amount of these minerals on their land for fertilization purposes, and often the excess manure must be removed from the farm for fertilization application elsewhere. Both manure and

<sup>1</sup> <http://groengas.nl/2011/09/06/oprichting-groen-gas-nederland-overgang-naar-groen-gas-begonnen/>

<sup>2</sup> [http://gasterraverslag.nl/2010/nl/jaarverslag/jaarrekening\\_2010/Jaarrekening\\_2010.pdf](http://gasterraverslag.nl/2010/nl/jaarverslag/jaarrekening_2010/Jaarrekening_2010.pdf)

digestate contain a lot of water, which makes transportation prohibitively expensive, and removal of digestate adds a considerable amount of costs to the production of biogas.

In the recently published report by LTO Nederland, a vision is presented on how this liability can be turned into an asset<sup>4</sup>. They foresee this taking place in the coming years, saving greenhouse gas emissions and creating a market for the byproducts of biogas production. Manure and digestate contain valuable minerals and compounds such as potassium, nitrogen and phosphorus. Phosphorus is vital to world food production and is becoming increasingly scarce. Due to this, phosphorus in particular could become a very important value added product associated with biogas production.

If LTO Nederland's vision is realized this could considerably lower the costs of biogas production.

In addition this would strengthen the position of green gas in the upcoming bio-based economy, where all biological materials will have to be optimally utilized.

### Gasification

In order to really scale up green gas volumes, anaerobic digestion will not suffice. To really increase the amount of green gas production, gasification is required, and this technology is still under development. ECN, Taqa, HVC and the province of 'Noord Holland' will invest in a demonstration gasification project of 12 Megawatts. The demonstration project is planned to become operational in 2013, and in 2017 it is expected that this will be followed by a larger scale commercial gasifier on the order of 50 – 100 Megawatts<sup>5</sup>.

### MOU

Looking beyond the Dutch borders there are also some interesting developments taking place. A memorandum of understanding was recently signed between Gazprom, Gasunie, Eurotechnica and BioGazEnergostroy. In this MOU these parties announced their intention to cooperate in the development of green gas in Russia and to make the benefits of that production available to the European Union.<sup>6</sup> According to Alexander Medvedev, the vice-chairman of Gazprom's



Figure 2: From left to right: Ludmila Orlova, Paul van Gelder, Alexander Medvedev and Sergei Chenin. Source: Gasunie<sup>6</sup>

management committee, Russia may be able to produce up to 35 billion cubic meters of green gas in the long run. In the last Quarterly I wrote about the amount of green gas that could realistically be expected in the near future in the Netherlands and came to the conclusion that it would be a relatively small contribution. If Russia were to realize their full green gas potential and if this green gas could be made available to the Dutch market, this picture would drastically change.

As described by Geert Joosten later in this issue, international trade of green gas is only possible if certification of green gas between trading nations is sufficiently harmonized.

### Domestic biogas in developing countries

Biogas can also play an important role in developing countries.

Organisations such as Hivos and SNV are implementing large scale domestic biogas programs in developing countries.

In Asia and Africa small scale biogas installations are providing renewable energy to rural households. Biomass is often freely available to rural households in the form of manure, whereas fuel for cooking is often absent or comes at a relatively high cost. Since the average ambient temperature in these regions is higher than in Europe, no additional heat is required to keep the digestion process going, and no expensive and complex technology is required. While biogas production in the Netherlands still requires subsidies, the decision to invest in a domestic biogas installation will yield an IRR of over 50% for a Tanzanian household. Besides providing cooking fuel, biogas can also provide light in the form of a very simple gas lamp, thereby extending the day in case an electricity grid is not present.

If biogas replaces fuelwood, the cleaner burning biogas prevents respiratory problems for both women and children (the women often work in poorly ventilated kitchens while looking after their children). The presence of a biogas installation also improves sanitary conditions, and the impact is even larger if the household's toilet is connected to the biogas installation. Finally, for many crops, it turns out that digested manure results in a higher yield, increased crop prices and less need for the addition of chemical fertilizer and pesticides.

The benefits of domestic biogas installations are widely recognized in countries such as Vietnam where almost 25 000 biogas plants have been installed in 2010<sup>7</sup>.

Despite the high potential returns after investing in a domestic biogas installation, the (relatively small) investment in a domestic biogas installation is often problematic due to a lack of financing options available to rural households.

Dutch utilities are in a good position to create a win-win situation. As long as national green gas production is insufficient to deliver green gas to households which would be willing to pay a premium for CO<sub>2</sub> neutral natural gas, this gas consumption could be compensated by enabling biogas production in developing countries. The biogas would not have to be physically delivered to the Dutch households, but a certification system would be required in order to ensure that the biogas is actually produced in developing countries, thereby displacing fossil fuel and preventing methane emissions from manure storage. Next to providing customers with affordable, CO<sub>2</sub> neutral natural gas, this would improve the livelihoods of poor farmers in developing countries.

5 <http://groengas.nl/projecten/groen-gashubs/overzicht-groen-gashubs/>

6 <http://www.lto.nl/media/default.aspx/emma/org/10760429/integrale+visie+duurzame+drijfmestverwaarding+visie+van+lto+nederland+augustus+2011.pdf>

7 <http://www.snvworld.org/en/ourwork/Documents/SNV%20Domestic%20Biogas%20Newsletter%20-%20Issue%204%20-%20January%202011.pdf>

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# Green gas injection in practice from a regional grid operator point of view

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Kirsten van Gorkum

Innovator Biogas Enexis

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***Manure, sewage, waste in landfills, organic waste, and other types of biomass can all be used to produce biogas. Biogas is produced in many different places in the Netherlands and throughout the world. This gas is usually converted directly into electricity with combined heat and power plants (bio-CHP), unfortunately in most cases the generated heat has no useful application. For optimal and sustainable utilization of the biogas it must be transported to locations where the full energy of the gas can be utilized.***

As the Netherlands has one of the most-effective natural gas grids in the world, this grid could also be utilized to transport biogas upgraded to natural gas quality.

Upgraded biogas is injected into the Enexis grid at 5 locations: Wijster, Tilburg, Groningen, Well and Witteveen. This biogas is produced from both organic material in landfills and organic waste, which has been collected separately. Crude biogas must be upgraded to natural gas quality before it is injected in the natural gas grid and when the gas is upgraded to natural gas quality, it is called green gas. The production of renewable energy is a hot topic today. Based on its mission to facilitate the energy transition, grid operator Enexis is working hard to simplify the injection of green gas in the gas grid.

## Green gas and the gas grid

Upgrading crude biogas to natural gas quality guarantees the safety and integrity of the grid and end-users equipment. Green gas, renewable gas upgraded to natural gas quality, must therefore meet the 'Additional requirements for green gas injection into the regional gas grid,' a set of requirements developed by the collective of Dutch grid operators together with biogas producers. This is done to safeguard the interests of both producers and consumers of natural gas in The Netherlands.

The Dutch natural gas grid is designed to provide gas from a central location (e.g. the gas field of Slochteren) to the end-users. This means that the amount of gas that needs to be injected depends on the amount of gas consumed at the end of the grid. Next to the gas quality requirements sufficient consumption on that part of the grid is necessary to inject green gas. The presence of a pipeline connection to the grid from a biogas plant with green gas does not "automatically" lead to smooth injection. The amount of green gas which can be injected into the grid equals the amount of gas that is consumed by the end-users connected to that part of the grid.

In the Netherlands most of the green gas is produced in rural areas which are not densely populated. This means few customers and a limited amount of gas consumption. Especially in summer, the demand for gas is low, since gas is mostly used for heating houses. It is often in summer that there is a mismatch between the demand and supply side. Priority for green gas cannot be compared with priority for renewable electricity. Where electricity producers can be switched off to create space for green electricity producers, for gas the question whether green gas can be injected depends on the demand by end-users.

## How to increase injection possibilities?

The future is one with sustainable energy supply. In this future the role for green gas is identified by Enexis. Multiple solutions are currently being explored by Enexis in order to increase possibilities for green gas injection and to break through the supply-demand mismatch.

- 1 Longer connection pipelines to a grid with a sufficient gas consumption
- 2 Back-feeding of the surplus gas into the national grid (higher pressure)
- 3 Collection pipeline with central upgrading (biogas hubs)

In Zwolle Enexis cooperated with the national grid operator GTS in a pilot project called 'Natuurgas Overijssel', (a joint venture of the waste processors ROVA and HVC). An 8-bar connection pipeline connects the production site to a compressor from which the connection is made to the 40-bar grid of the national grid operator GTS. The party that injects the green gas in the grid carries the costs of the connection pipeline and the compression of the gas. Since these costs are relatively high, a long connection pipeline is not usually a viable option for smaller biogas producers when faced with capacity problems.

Currently a study is being performed concerning back-feeding surplus gas to the national grid which is operated at a higher pressure. In summertime or when more producers request a connection to the regional grid and gas consumption is lacking, a large compressor feeds the excess gas from the regional grid (8 bar) back into the national grid (40 bar). In order to use as little energy as possible, discussions are taking place between the regional and national grid operator to operate the national grid at a lower pressure during summertime, when smaller volumes need to be transported. Even though discussions concerning responsibilities and financial models are still taking place, Enexis is working on a back-feeding pilot in Groningen to learn more about the technical possibilities and operational issues in practice.

The third category of 'increasing injection possibilities' are also put in practice by Enexis. In the northeastern part of Friesland, in Wijster and the area of Salland, biogas hubs are being developed. In rural areas, transporting the biogas to a central location - a biogas hub - seems to be an obvious solution. Several producers inject biogas into a central pipeline which transports the gas to either an industrial consumer or an upgrading facility that upgrades the biogas to green gas quality for injection into the natural gas grid. Upgrading biogas to green gas is a very costly process. For smaller projects it is almost impossible to create a viable business case since the upgrading facilities that are required to produce green gas require large investments. A biogas hub may offer a solution here.

In order to secure the safety of the maintenance engineers and the direct surroundings of the upgrading facility, safety requirements are set. This means that raw biogas cannot freely be transported through a biogas pipeline and not just any pipeline can become a biogas pipeline. In order to be transported safely it has to meet the specifications that have been set for biogas. The biogas must meet the maximum water dew-point and components like water sulphate and ammonia must be limited. A biogas hub is more than the technical engineering of an infrastructure. Commitment of local-, regional- and national government, producers, financing parties and grid operators is necessary next to the willingness

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to invest in a concept of which the risks – both commercial and technical – are not all visible. The project in the North-Eastern part of Friesland is unique as the upgraded green gas, 6500 m<sup>3</sup>/h, will be injected in the national grid (40bar). Enexis and Stedin have taken care of the basic engineering, the permits and licenses and will invest in the biogas hub. Producers are willing to commit themselves to the project and are waiting for the necessary subsidies from the Dutch government (SDE+), as without subsidy this project would not yet be financially feasible. The biogas hub in Wijster has received part of the required subsidies and the Salland biogas hub is still in the development phase. For the development of a biogas hub many parties, sometimes competitors, must all work together.

### **Biogas hubs and pipelines**

Biogas as such is not covered in the Dutch Gas law, nor is a European or national norm formulated regarding the operation and management of a biogas pipeline. In the present situation biogas pipelines and hubs can be developed by any commercial party. Even though it concerns a free-market activity, in practice few are in development and the ones that are progress slowly.

Enexis could perform a vital role in providing biogas infrastructure activities for two reasons. (1) The fact that the activities are not adopted by the commercial market and (2) because of its impeccable track record in safe and reliable gas transportation and distribution. Finally, it is very likely that the regional grid operator will be approached in case of failures and leaks of a pipeline with a gas-like-substance and where safety must be served. For these reasons, Enexis advocates that construction and maintenance of biogas infrastructure should become one of their statutory duties.

### **Conclusion**

The most suitable solutions for the sustainable use of biogas depend on the location and specific situation. In close cooperation with market participants Enexis will assess the optimal solution for each specific case. This cooperation goes further than the statutory duties in order to address the challenges arising from the transition to a more sustainable energy supply.

# Development of a Decision Support Tool for Investments in the Gas Distribution System

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## Introduction

It is expected that the share of bio-methane in the Dutch gas supply mix will increase significantly in the next decade – from the current 0.1% to 12% in 2020. The bio-methane supply chain is shown in Figure 1. In the first step, the biomass is produced and subsequently transported to the digester installation – the biomass consists of manure and a co-substrate, e.g. maize. In the study presented in this article, biomass is supplied by farmers. The digestion process produces biogas consisting of 50-65% methane – for comparison Dutch natural gas consists of 83% methane. In the subsequent step, upgrading, unwanted components are removed and the methane content is increased, in order to obtain a gas with burning properties similar to that of natural gas.

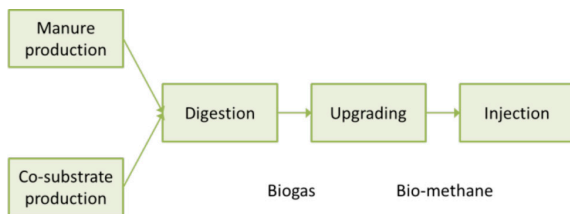


Figure 1: Bio-methane supply chain [3]

Due to the small scale of bio-methane installations, it is economically not efficient to inject the bio-methane in the national transport grid. Therefore, the bio-methane is likely to be injected in the gas distribution grid. The gas distribution grid is traditionally not used as a feed-in point for produced gas, and the injection of bio-methane in the gas distribution grid leads to several challenges. Among others, the gas demand in the distribution grid may not be sufficient to take up all the bio-methane produced, especially in the summer when gas demand is at its lowest. Furthermore, if one or more farmers want to use their biomass to produce bio-methane, it should be investigated how and where each step of the bio-methane supply chain takes place. One option is to perform each step of the supply chain at the farm site for each individual farmer. However, the digestion and upgrading equipment is expensive. It might therefore be beneficial to share the investment of, for instance, an upgrading plant with several farmers and consequently lowering the investment costs for the upgrading plant per farmer. Though investment costs for the upgrading plant are lowered in this way, it also incurs extra costs, since a pipeline has to be laid to transport the biogas from the digester to the upgrading plant – or in case a digester is shared, the farmer should transport the biomass to the digester. Hence, a trade-off has to be made between these different costs [1]. The preferred configuration is largely dependent on the specific situation, and therefore the choice regarding the best option varies from situation to situation. Therefore, we are developing a Decision Support Tool (DST) that gives location specific advice regarding investments in bio-methane projects.

In this article, we present the prototype of the eventual DST we are developing. By means of a case study[2], we explain the basics of the DST. In the case study several farmers in the vicinity of the city of Zutphen would like to use their biomass to produce bio-methane. The produced bio-methane will be injected in the natural gas grid of Zutphen.

## The case study

Figure 2 shows the layout of the 8 bar grid of Zutphen. The blue arcs indicate the pipelines, and the blue squares indicate the district stations, which in this model are considered to be the gas consumers. In the vicinity of Zutphen there are several farmers with biomass available for bio-methane production, they are indicated with black plusses. The 8 bar grid, the gas consumers, the farm locations, and the biomass availability for each farm are loaded into the DST.

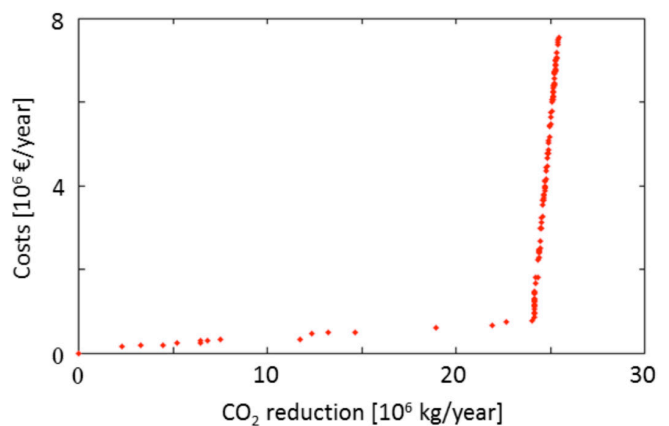


Figure 2: 8 bar grid of Zutphen and the farms with biomass available for bio-methane production

Once all the data is loaded into the DST, it starts to explore a great number of potential solutions to utilize the biomass. The solution should preferably minimize the yearly costs and maximize the CO<sub>2</sub> reduction achieved by replacing natural gas by bio-methane. For this step, the DST uses building blocks to generate solutions. The building blocks the DST uses are:

- Truck: To transport the biomass from the farm to the digester station in case the biomass is not digested at the farm site
- Pipelines: To transport biogas from the digester to the upgrading plant in case these two steps are not performed at the same location
- Digester station: Converts biomass into biogas that contains 57% methane
- Upgrading plant: Converts biogas into bio-methane, i.e. natural gas quality
- Injection station: Compresses the gas to 8 or 40 bar and by means of a pipeline feeds the bio-methane in the 8 bar grid, or the gas receiving station (connected to the 40 bar grid) respectively

The DST places and scales the building blocks when generating potential solutions.

For this study, 10.000 possible solutions were generated. For each solution, the yearly costs and the yearly CO<sub>2</sub> emission reduction were determined. Among the 10.000 solutions there is not a single solution that optimizes both performance indicators. However, several solutions can be considered “pareto optimal”; a pareto optimal solution is a solution for which there cannot be found another solution with a better performance indicator without deteriorating the other performance indicator. Figure 3 shows the set of pareto optimal solutions derived

from the total set of 10.000 solutions. It can be seen that reducing more CO<sub>2</sub> on a yearly basis leads to higher yearly costs. Therefore, when deciding on the preferred solution, a trade-off has to be made between yearly costs and yearly CO<sub>2</sub> emission reduction.

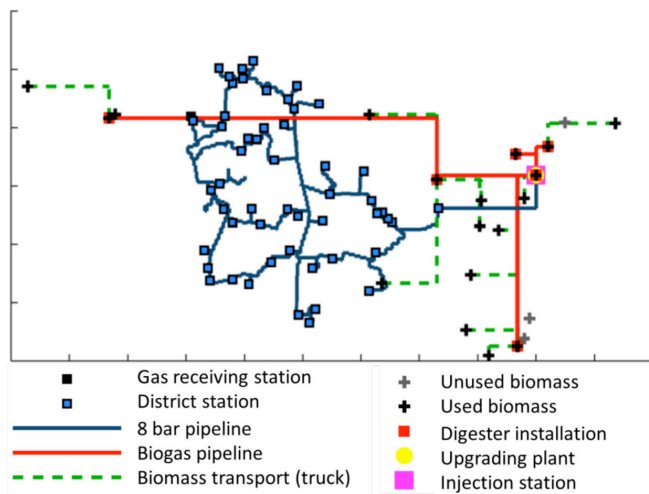


Figure 3: Performance indicators of the pareto optimal solutions

To illustrate what kind of solutions the DST generates, Figure 4 shows one of the solutions that is pareto optimal. As can be seen, in this solution, sometimes the biomass is transported by truck – which is indicated by a dashed green line – to a digester further away. For instance, the biomass from the farm in the top left of the figure is transported to the neighbouring farm where a digester installation is located. The biogas produced at this location is transported by a biogas pipeline – indicated with a red line – to a central upgrading plant – yellow circle. In this configuration, one upgrading plant is shared by all the farmers. At the location of the upgrading plant, the gas is also compressed to the appropriate operating pressure in the injection station – magenta square – and subsequently injected in the 8 bar grid of Zutphen.

### Lessons learned

The case study showed that the DST is a useful tool to provide insight in the available investment options. Once the starting configuration is loaded into the DST, it generates a multitude of solutions. The plots easily shows how each solution performs compared to the others. Hence, the tool promises to be of great added value to the Distribution Service Operators (DSOs).

In order to increase the added value of the DST for the DSOs, it needs some further improvements. First of all, a number of performance indicators will be added to increase insight into the available solution space; among others, we will add yearly green gas volume produced, investments required in the gas grid, and the energy balance for each solution. Secondly, the user interaction of the tool should be significantly improved.

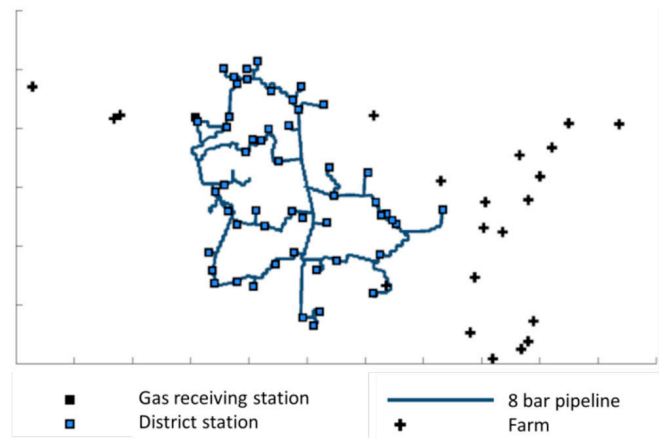


Figure 4: Example of a generated solution

### Concluding remarks

The developed prototype is a first step towards a DST which will have more functionality. In the eventual DST we will incorporate different types of foreign gas. Furthermore, interaction between the electricity grid and the gas distribution grid – e.g. the injection of hydrogen in the gas grid to buffer the fluctuating energy supply of solar PVs and windmills – will be incorporated.

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### About the author

Taede Weidenaar studied Applied Physics (BSc) and Mechanical Engineering (MSc) at the University of Twente. Currently, he is working as a PhD student at the department of Engineering Technology of the University of Twente. His PhD study focuses on the way the future Dutch gas distribution system should be shaped. For his research he will develop a Decision Support Tool that will aid the Distribution Service Operators in their decision making process on future investments in the gas distribution system. His research is part of a project in the Dutch research programme on gas, EDGaR.

***Most of the biogas produced in the Netherlands is used to produce green electricity, however the waste heat of the gas engine often cannot be used effectively because of the remote location of the production sites. In that case the overall energy efficiency of the production chain is very low. When the biogas is treated to a gas quality that can be fed into the public gas grid (it then is called green gas) the overall energy efficiency is considerably higher. This has been rewarded in the Dutch SDE+ subsidy and biogas producers have shown an keen interest in the production of green gas under this scheme. If all projects awarded in 2011 are realised the yearly production volume of green gas would increase by more than 195 MCM.***

Feeding green gas into the grid dramatically increases the number of potential customers : all companies and private persons connected to the grid. However, after being fed into the grid, green gas mingles with the fossil gas and cannot be distinguished from it. To be able to trade and sell green gas it is essential to have a certification system. In this system a certificate is issued for each MWh of green gas that has been fed into the grid. The sale of green gas takes place by delivering (mainly fossil) gas from the grid plus the corresponding number of certificates. There need not be a physical connection between the points of injection and consumption other than that they both are connected to the public gas grid. The certificates guarantee the green origin of the gas.

It is clear that the trust market parties have in the certificate system hinges on the reliability of the certificate's issuing body. Customers must not have any doubts whatsoever regarding such questions as: was the green gas actually fed into the grid, was the gas actually of a green origin, can no double counting of certificates take place etc. In the Netherlands Gasunie has founded a certificate Issuing Body (IB), Vertogas. Vertogas takes all possible measures to guarantee the validity of the certificates. Examples of these measures include the strict application of rules to the accuracy of the energy metering, that each certificate is uniquely numbered, that it states the identity of the production site, the date of production, the nature and origin of the feed that was used to produce the green gas, whether subsidy was received in the production process etc.

The practical operation of the system is as follows. A producer of green gas asks Vertogas to register his installation. Vertogas then carries out a physical inspection of the plant and an audit of the procedures for production and transfer of the necessary information to Vertogas during the operation phase of the plant. After approval by Vertogas the producer can start to feed green gas into the grid. He chooses a trader to which he sells the green gas. The trader receives a certificate for each MWh of green gas fed into the grid. The metering of the number of MWh is carried out by an independent metering company. The latter transfers the metering data to Vertogas. Vertogas keeps a kind of "bank account" of certificates for each trader. A trader can sell his certificates to another

trader. They inform Vertogas of the deal and the certificates are transferred to the account of the new owner of the certificates. Of course the trader can also sell green gas to an end consumer. When doing so Vertogas cancels the corresponding number of certificates from the trader's account.

At present not all gas labelled green is traded via the Vertogas certification system. This is confusing for the customers and may be detrimental to the public's trust in green gas. It is a positive development that minister Verhagen recently announced that Vertogas will be given a legal status in the near future.

In the Netherlands there is no certification system for biogas as such. This is a pity because the direct use of biogas, for example for heating, is an economical way of using the energy released from biomass. Hardly any treatment of the biogas and compression needs to take place, so avoiding considerable costs. This results in a low price per MWh. The users of biogas may want to claim the green nature of the biogas. In that case the certificates are cancelled when the gas is used. Via the IB the user can prove that he has burned gas from a renewable source. Alternatively, the user may not desire to use the green claim himself, but want to sell the green value of the biogas to somebody else. This is possible via the certificates.

We recommend that a study is carried out investigating whether and under what conditions a biogas certification scheme can be set up in parallel to the green gas certificate system. Requirements for the protocols of certification should be defined.

Another possible step is the international trade of green gas. Certain countries, e.g. Germany, have a high production level. The demand for green gas may be large in other countries, creating an interesting market for green gas abroad. It is clear that this international trade will take place via certificates: the certificates are traded, rather than the physical gas. The trade of certificates should go via the Issuing Bodies in both countries. The traders in the exporting and importing country inform their IB that a trade has been arranged, and the national IB of the exporting country then cancels the corresponding number of certificates. Finally, the IB in the importing country generates new ones in his national system for the importing trader. Essential in this scheme is that the certificates in both countries are representing the same green properties of the gas, i.e. they are interchangeable. The simplest way to realise this is by having identical rules for green gas in both countries. At present rules vary across Europe. This need not rule out the possibility of international trade, provided the essential rules are identical. To arrange this bilaterally between countries is probably easier than for the whole of Europe, especially as the Renewable Energy Directive does not apply to green gas. A good start may be to enable trade of green certificates between Germany and the Netherlands. Once up and running more countries may join the scheme. A positive development in this respect is that Vertogas and DENA in Germany are discussing these kinds of possibilities. The same holds for the signing of a Memorandum of Understanding between Gasunie and Gazprom plus Biogazenergostroy in Russia. They will study the possibility to export Russian green gas (certificates) to the Netherlands.

There are interesting times to come for green gas.

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## Recent Publications

### ***Economist Intelligence Unit, November 2011. Breaking new ground: A special report on global shale gas developments. The Economist.***

Worries about climate change are deepening in many countries. Proponents of gas, which burns cleaner than coal, suggest that it could be part of the answer—but preferably indigenous gas, for the sake of energy security. At the same time, even as energy demand surges ahead, the giants of the oil industry are finding it harder than ever to tap new reserves, which is forcing them to look to previously neglected, harder-to-reach hydrocarbons. Among these, previously disregarded shale gas reserves are generating the most enthusiasm. The groundwork for this has been a remarkable upswing of activity in the US, where over the past decade innovative techniques have propelled shale gas from irrelevance to a position where it now makes up one-quarter of all natural gas production. And although the shale gas story has been overwhelmingly a US one to date, the search for shale is accelerating around the world. This special report brings together a collection of recent articles looking at fledgling shale gas developments worldwide, with a focus on the countries thought to hold the largest reserves. This report is available at: [http://www.eiu.com/public/topical\\_report.aspx?campaignid=shalegas](http://www.eiu.com/public/topical_report.aspx?campaignid=shalegas)

### ***International Energy Agency, November 2011. World Energy Outlook 2011.***

The World Energy Outlook (WEO) 2011 brings together the latest data, policy developments, and experience of another year to provide robust analysis and insight into global energy markets, today and for the next 25 years. This edition of WEO gives the latest energy demand and supply projections for different future scenarios, broken down by country, fuel and sector. It also gives special focus to such energy sector issues as: 1) Russia's energy prospects and their implications for global markets; 2) the role of coal in driving economic growth in an emissions-constrained world; 3) the implications of a possible delay in oil and gas sector investment in the Middle East and North Africa; 4) how high-carbon infrastructure "lock-in" is making the 2°C climate change goal more challenging and expensive to meet; 5) the scale of fossil fuel subsidies and support for renewable energy and their impact on energy, economic and environmental trends; 6) a "Low Nuclear Case" to investigate what a rapid slowdown in the use of nuclear power would mean for the global energy landscape, and 7) the scale and type of investment needed to provide modern energy to the billions of the world's poor that do not have it.

This book is available at: <http://www.iea.org/w/bookshop/add.aspx?id=428>

### ***Katja Yafimava, November 2011. The Transit Dimension of EU Energy Security: Russian gas transit across Ukraine, Belarus and Moldova. The Oxford Institute for Energy Studies.***

This is the first book to provide an in-depth analysis of market, legal/regulatory, and energy security aspects of the transit of Russian gas to Europe across western CIS countries – Ukraine, Belarus, and Moldova – to Europe. The book analyses how EU transit, and hence energy, security is affected by the governance structures of the Eurasian gas network and by asymmetrical power relations between its actors, in particular between Russia and western CIS states and their national gas companies. The book views the Eurasian gas network as the overlap and interaction of four spaces: the regulatory space, the contractual space, the space of flows, and the space of places. It concludes that discontinuities

between and within the spaces adversely affect EU gas transit security, and suggests ways of reducing these discontinuities and minimizing their negative effects. Threats to the security of Russian gas transit across western CIS countries are identified, and reasons for unresolved Russia–western CIS bilateral issues which led to the appearance of these threats are explained, as are reasons why existing bilateral frameworks (supply and transit contracts and intergovernmental agreements) proved inadequate to ensure security of transit. EU energy policy gaps are identified, and the reasons which reduced the Union's ability to deal with such threats, and the ways in which transit security could be incorporated into the existing policy frameworks, are explained. The book shows how multilateral frameworks (the Energy Charter Treaty and the Energy Community Treaty) could contribute towards increased security of transit, and how transit security threats can be reduced through the joint employment of bilateral and multilateral frameworks. This book is available at:

<http://www.oxfordenergy.org/shop/the-transit-dimension-of-eu-energy-security-russian-gas-transit-across-ukraine-belarus-and-moldova>

### ***James Henderson, November 2011. Domestic Gas Prices in Russia – Towards Export Netback? The Oxford Institute for Energy Studies.***

The paper by James Henderson examines the domestic gas price developments in Russia and the progress that has been made towards the target set by Vladimir Putin for regulated gas prices to reach parity with the European export netback price by 2011. The first sections of the paper give a brief history of gas prices in Russia in the post-Soviet era from 1991 to 2006 and discuss the introduction of the netback parity target together with its implications for the Russian gas sector. Following sections discuss the current state of the debate on domestic gas prices and examine the implications of reaching a netback parity target by 2015. The last two sections of this paper examine the impact of a number of factors on domestic gas prices, including gas sector reform in Europe, electricity sector reform in Russia and the ongoing diversification of a number of gas producers into the power sector, the improving economics of Russian gas production as the importance of non-Gazprom producers grow, and many others. This paper concludes that Russian domestic gas prices are not likely to reach European netback levels any time soon, but that the momentum of the past five years towards significantly higher domestic prices will continue, leading to an eventual liberalization of the Russian gas market. Over the next decade, this could create fundamental changes in Russia's relationship with European gas markets with potential competition for available supplies between domestic and European export markets.

This paper is available at: [http://www.oxfordenergy.org/wpcms/wp-content/uploads/2011/11/NG\\_57.pdf](http://www.oxfordenergy.org/wpcms/wp-content/uploads/2011/11/NG_57.pdf)

### ***David Buchan, October 2011. Expanding the European dimension in energy policy: the Commission's latest initiatives. The Oxford Institute for Energy Studies.***

This paper relates to events taking place at the European level to help the European Union towards its ambitious 2020 energy and climate goals. Specifically, this paper tracks the European Commissions' initiatives in 2011 to streamline national planning approval of vital energy infrastructure, to use EU funds to leverage more private finance for energy projects, and to lend some reality to a common external energy policy through Commission-led negotiations with foreign energy suppliers on international infrastructure. This paper analyses the

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problems that the Commission initiatives seek to resolve, since these initiatives awkwardly coincide with the eurozone crisis. David Buchan broadly endorses Brussels' attempt to kick-start implementation of Europe's 2020 energy and climate goals. He suggests the Commission go a step further by taking advantage of the forthcoming treaty revision to propose a constitutional amendment on EU states' energy mix. The paper is available at: [http://www.oxfordenergy.org/wpcms/wp-content/uploads/2011/10/SP\\_23.pdf](http://www.oxfordenergy.org/wpcms/wp-content/uploads/2011/10/SP_23.pdf)

***WWF and Ecofys, December 2011. EU Climate Policy Tracker 2011.***

Limiting the rise in the average global temperature to 2°C has been the EU goal since 1996, and in December 2010 the UN recognised the need to consider a 1.5°C limit. Avoiding overshooting these levels will require massive emissions reductions – in the order of 80-95% for industrialized countries, such as those in the EU. The next ten years are crucial in establishing whether society will be able to make this transition, or whether temperature increase limits will be irreversibly missed. Last year, the European Union Climate Policy Tracker (EU CPT) investigated each member state's implementation of policy and legislation, and rated their progress towards a 2050 vision of deep decarbonisation using renewable energy. The uniquely developed rating scheme, modelled on appliance efficiency labels (A-G, where G is the lowest score), gave an indication of how member states were doing compared to a 'low-carbon policy package'. The average score was an 'E', indicating that the level of effort needed to treble, to be on a pace to reach the 2050 vision.

This report builds on last year's EU CPT by giving an update on action in member states, and an indicative trend in the rating, as well as adding a new section on EU policy. The overall conclusion of this report is that current efforts in Europe still remain insufficient to meet a low-carbon vision.

This report is available at: <http://www.climatepolicytracker.eu/>

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***Ahmad Faruqui & Doug Mitarotonda, November 2011. Energy Efficiency and Demand Response in 2020 – A Survey of Expert Opinion. The Brattle Group.***

Compared to the European Union, which has a definite target for energy efficiency improvement by 2020, the US as a whole does not yet have any similar targets. Nevertheless, some states such as Connecticut, Maryland, and Pennsylvania have established specific numerical targets while others, such as California, have made energy efficiency and demand response part of their energy action plan.

The Brattle Group in cooperation with Global Energy Partners has recently carried out a survey with the central question of "what is the likely impact of energy efficiency and demand response going to be on customer usage by the year 2020?" Almost 200 experts in the US and Canada participated in this survey, representing various facets of the industry – from academics to consultants, utilities to regulators and consumer to environmental NGOs. The overall observation of this survey was the following: "the experts expect that US electric consumption will decline by between 5 and 15 percent by the year 2020, compared to what it would have been in the absence of additional energy efficiency measures. Concerning natural gas consumption, this savings are in the range of 5 to 10 percent, compared to what is would have been otherwise".

All results of this survey are available at: [http://www.brattle.com/\\_documents/UploadLibrary/Upload990.pdf](http://www.brattle.com/_documents/UploadLibrary/Upload990.pdf)

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# Conference Notes

## **IEA World Energy Outlook 2011 in the Hague**

After an introduction of Maria van der Hoeven (chairman IEA, former Dutch minister of Economic Affairs), Fatih Birol (Chief Economist of IEA) presented the most interesting findings:

Gas will be the 'lucky' fuel. It is the cleanest of the fossil fuels and is relatively abundant, accessible and cheap. It is becoming more attractive in light of the nuclear disaster in Fukushima and the resulting global disinterest in nuclear energy and because of China's plan to focus on natural gas to meet increasing energy demand. Gas is lucky, because it will benefit as the default fuel. According to Birol, the next age could be a golden one for natural gas on the condition that the industry does everything in their power to extract natural gas (conventional and shale) in a sustainable and clean manner. Only if the industry will apply best practice in regards to the environment (at 10-15% higher cost), than unconventional gas has an important future in Europe especially. Coal on the other hand, is the 'forgotten' fuel. On conferences and energy events much is said about oil, gas, nuclear and renewables, but not about coal despite the fact that it makes up 50% of global power production. The share of coal used for power production will continue to be large due to the demand of developing countries, such as China and India.

The phase-out of nuclear in some countries and the decreased activity in others is undesirable from both an environmental (more emission of CO<sub>2</sub> associated with fossil fuels) and an energy supply (energy supply is less diversified) perspective.

Some 50% of global efforts to reduce climate change must come from improved energy efficiency and the largest improvements can be made in countries such as Russia.

The window of opportunity to act together against climate change to put the world on a path leading to a temperature increase of 2 degrees Celsius is closing fast. The world is 80% locked in on a path that leads to a larger temperature increase. By the end of 2017, this certainty will be 100%, and all opportunity to get on a 2-degree path will be lost.

## **Symposium 'Energie in 2030'**

The first debate during this symposium dealt with real energy savings and related issues. The saving of energy results in lower energy bills on the household level. However, we tend to invest the saved money in other energy-consuming products and services. The discussion focused on the manner in which real energy savings can be achieved in the light of this reality.

The next discussion was about 'Obtaining insight into sustainability and focused on the absence of a certification scheme in the energy sector. In this regard, a certificate implies that the whole production process of energy (it applies to the complete chain) meets certain standards. To introduce such a scheme, the government should take the initiative because companies do not really have an incentive to introduce such a scheme themselves, according to the debaters.

The subject of the third discussion round was 'between scarcity and abundance'. It concerned the relationship between renewable sources of energy, their implementation on shore, fossil sources of energy, their continuous use and resulting (climate) problems in the future and, more in general, what must be yielded in financial, environmental and spatial terms.

The final debate was called 'Towards a new model of earning money with energy in 2030' and dealt with the choices that must be made right now in order to make money with energy in 2030. At this time point it is expected that fossil fuels, natural gas in general will still play a dominant role in the energy mix, next to the increased penetration of renewables.

## **Eurogas Annual Conference**

The day started with an opening word after which Laurent David (GDF Suez) presented the Eurogas Roadmap 2050. During the subsequent discussion, it became clear that companies and institutions (IEA, GasTerra, GDF Suez, WWF) see a prominent role for natural gas in the future energy supply to reduce emissions until 2030. Following this, there was a discussion about attracting investment in the European internal market. It appeared that the regulatory framework supporting the market is very uncertain, according to Domenico Dispenza (ENI), which makes investment difficult. Next to this, the future natural gas market will be characterized by a combination of long-term contracting (only if it leads to a better functioning of the internal market) and spot pricing, the EC stated.

Next, Fabrizio Barbaso (EC) gave an overview of the EU's future external energy policy. During the subsequent discussion it became clear that the EU external energy policy is focussing on the governmental level and not the company level. The goal is a better functioning of the internal market and to achieve this, a better grip is needed on intergovernmental agreements. The final speech of the day was held by Philippe Lowe. He talked about the completion of the European internal energy market in 2014 and the further steps that must be taken to better the functioning of the internal market, such as to further implement the 3rd Energy Package, harmonising market and network operating rules and enhancing investments in infrastructure.

## **Hamburg Intelligent Cities Expo**

The first day at the Intelligent Cities Conference Hamburg focussed on the smart city pilot programs already in operation and projects that are in development. The main message that was conveyed in all presentations is that Smart City and Smart Grid projects are a joint effort between several parties. No single organisation or company is able to implement this alone, beneficial cooperation is the main solution. Additionally, Simon Giles of Accenture emphasized that the added value of smart grids must be made apparent to all stakeholders in order to ensure their adoption.

The second day of the Expo was devoted to governance issues surrounding intelligent cities. Andreas Hermelink of Ecofys emphasized that net-zero energy buildings need to compensate for others that cannot be renovated sufficiently or cost effectively, such as historic, protected buildings. Richard Bellingham from the University of Strathclyde underscored the fact that cities must be designed in a resilient manner in order to cope with socioeconomic change.

The third and final day of the Expo discussed intelligent mobility. Here, Peter Lindlahr of Hysolutions discussed the changes in mobility implied by social changes, such as the fact that newer generations are less dedicated to the personal automobile. Generally, an emphasis was placed on the examination of cities as an integrated space in order to achieve the maximum level of integration and efficiency among the various modes of transport and activities taking place. The success of congestion charges was demonstrated by various examples, and the need to examine new sources of revenue (due to the fact that less income will be generated from road taxation) was discussed. Finally, a overarching theme present throughout the conference was the importance of politicians communicating to the public that significant increases in the prices of energy are expected in the future, something that is not currently taking place to a large enough extent.

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# Conferences 2012

## January

January 23-25: Berlin, Germany

### **Gas to Power Europe Forum**

[www.gastopowereurope.com/](http://www.gastopowereurope.com/)

January 23-25: West Sussex, UK

### **EU and UK Gas Security of Supply**

<http://www.wiltonpark.org.uk/en/conferences/policy-programmes/european-union-and-its-neighbours/?view=Conference&id=592573782>

January 24-27: Vienna, Austria

### **European Gas Conference 2012**

<http://www.theenergyexchange.co.uk/european-gas-conference-2012/s13/a214/>

January 25-26: London, UK

### **Esco Europe**

[www.esco-europe.com](http://www.esco-europe.com)

January 26-27: Berlin, Germany

### **Gas Transport & Storage Summit 2012**

<http://www.gtseven.com/>

January 31-February 1: Brussels, Belgium

### **EU Energy Law & Policy, 7th Annual Conference**

<http://www.euenergyconference.com/>

## February

February 1-2: London, UK

### **Gas to Power**

[www.smi-online.co.uk/events/overview.asp?is=5&ref=3851](http://www.smi-online.co.uk/events/overview.asp?is=5&ref=3851)

February 6-8: Istanbul, Turkey

### **EMEA Unconventional Gas Exploration and Production Forum**

<http://www.cvent.com/events/unconventional-gas-exploration-and-production/event-summary-dff2d29a930f45a783f78363f130a8dd.aspx>

February 7-9: Essen, Germany

### **E-World Energy & Water 2012**

<http://www.e-world-2012.com/en/congress/programme/>

February 8: London, UK

### **Carbon Capture & Storage Forum**

[http://marketforce.eu.com/Conferences/ccs12/?utm\\_source=www.euagenda.eu&utm\\_medium=event\\_calendar&utm\\_campaign=ccs12](http://marketforce.eu.com/Conferences/ccs12/?utm_source=www.euagenda.eu&utm_medium=event_calendar&utm_campaign=ccs12)

February 8-10: Marseille, France

### **Global Energy Forum**

[oilgas.flemingeurope.com/global-lng-forum/](http://oilgas.flemingeurope.com/global-lng-forum/)

February 29 – March 2: Wels, Austria

### **World Sustainable Energy Days**

[www.wsed.at/en/programme/](http://www.wsed.at/en/programme/)

## March

March 6-7: Amsterdam, the Netherlands

### **Carbon Market Insights**

[www.pointcarbon.com/events/conferences/cmi2012/](http://www.pointcarbon.com/events/conferences/cmi2012/)

March 6-8: Berlin, Germany

### **European Gas Market Forum**

<http://www.cvent.com/events/european-gas-market-forum/event-summary-17f06992f6584036baac7adc4f18bc7c.aspx>

March 13-14: Düsseldorf, Germany

### **Energy Storage**

<http://www.energy-storage-online.de/>

March 13-14: Barcelona, Spain

### **Unconventional Gas Forum 2012**

<http://www.ug-forum.com/>

March 13-15: Rotterdam, the Netherlands

### **World Biofuels Markets 2012**

[www.worldbiofuelsmarkets.com/EF/?sSubSystem=Prospectus&sEventCode=BF1203NL](http://www.worldbiofuelsmarkets.com/EF/?sSubSystem=Prospectus&sEventCode=BF1203NL)

March 21-22: Oslo, Norway

### **European LNG Forum**

[http://www.lngjournal.com/lng/index.php?option=com\\_k2&view=item&layout=item&id=2057&Itemid=157](http://www.lngjournal.com/lng/index.php?option=com_k2&view=item&layout=item&id=2057&Itemid=157)

March 26-28: Moscow, Russia

### **Russia 2012 Offshore 7th Annual Conference & Exhibition**

<http://www.theenergyexchange.co.uk/russia-offshore-2012-7th-annual-meeting/s13/a244/>

March 26-29: Warsaw, Poland

### **Unconventional Gas & Oil Summit**

<http://www.informaglobalevents.com/event/unconventionals/Accommodation>

March 26-29: London, UK

### **Smart Energy Management**

<http://www.terrapinn.com/2012/smart-energy-management-world-europe/>

March 27-29: Marcliffe, Aberdeen, UK

### **Oil & Gas Outlook North Sea**

<http://www.energydelta.org/mainmenu/edi-intelligence-2/our-services/upcoming-conferences-and-seminars>

March 29: London, UK

### **The Smart Utility Forum**

<http://marketforce.eu.com/Conferences/smartutility12/>

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## April

April 16-20: Amsterdam, the Netherlands  
**Flame 2012**  
<http://www.informaglobalevents.com/event/flame-conference>

April 17-20: Maastricht, the Netherlands  
**2nd European Energy Conference**  
<http://energy-conference.eu/>

April 16-18: Trondheim, Norway  
**Technoport 2012**  
<http://technoport.no/conference-2012/>

April 26-27: Copenhagen, Denmark  
**Annual Euroheat & Power Conference**  
<http://conference2012.eu/>

## May

May 10-12: Florence, Italy  
**International Conference on the European Energy Market**  
<http://eem12.org/>

May 14-16 or April 22-25: Berlin, Germany  
**B4E Business for the Environment – Global Summit 2012**  
<http://www.b4esummit.com/>

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## June

June 4-8: Kuala Lumpur, Malaysia  
**25th World Gas Conference**  
<http://www.wgc2012.com/>

June 12-14: Rome, Italy  
**International Energy Program Evaluation Conference**  
[www.iepec.org/?page\\_id=975](http://www.iepec.org/?page_id=975)

June 12-14: Cologne, Germany  
**Renewable Energy World Europe 2012**  
<http://www.renewableenergyworld-europe.com/index.html>

June 18-22:  
**20th European Biomass Conference & Exhibition**  
<http://www.conference-biomass.com/>

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