Figure 1: Shale oil drill in the Neuquén Province of Argentina (Seattle Times 2010)

FRACKING

SPECIAL REPORT ON HYDRAULIC FRACTURING

NOVEMBER, 2012

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CÓRDOBA, ARGENTINA

TABLE OF CONTENTS

INTRODUCTION

By Jorge Daniel Taillant

Energy needs are once again at the heart of discussions around our society's development needs. This time the issue is shale gas discoveries and future production in Argentina.

Scientific evidence that is now beyond doubt confirms that over the last several centuries of industrial development and due to our more recent acceleration consumption of CO2-emitting fossil fuels, as well as the massive emission of non-CO2 short-life climate pollutants --SLCPs (such as black carbon, methane gas and HFCs) are rapidly driving our global climate and atmosphere into irreversible collapse.

While much of the world is slowly turning to explore the largely untapped potential of renewable sources of energy, such as solar and wind power, to meet our energy consumption needs, petroleum and gas producers, as well as many fossil fuel rich countries, are insisting on perpetuating global dependence on fossil fuels as the motor for global economic growth and prosperity.

As our knowledge and capacity to utilize renewable energies to replace climate deteriorating fossil fuels advances, so does the petroleum sector's capacity to drill for more oil in hard to reach places, in the depth of our oceans and deep in the earth's surface, where after traditional well depletion, fossil fuel may lie embedded in the pours of rock.

In the boom of oil production in the 19^{th} and early 20^{th} Century, getting at these *non-conventional* fuel deposits was not economically feasible. It was simply easier to go for the low hanging fuel in the form of large wells that readily offered large oil deposits ready for extraction. But as these wells dry up, and technology improves to extract more hard to get reserves, such as shale gas, the options for propagating an economic model dependent on fossil fuel survives.

We as an organization oppose the continued reliance on fossil fuels to underpin our supposed global economic development. In a country with ample solar and wind potential, we cannot accept a national development model where long term *development* implies the short tem *destruction* of our delicate global ecosystem. There is also a global ethical question in play in this decision, we need to think locally, but we must also act globally. The continued bet on fossil fuels to resolve our energy needs, is simply not a viable alternative.

We are greatly troubled by the long term forecasts by the global petroleum industry, which shows a steady distribution in terms of energy types of fuel consumed over the next 50 yeas, (in terms of fossil vs. renewables, which is forecast at about 85%/15%) with a parallel and exponential expansion of energy consumption. In other words, petroleum producing companies forecast a significant increase in the quantity of renewables used in the next 50 years, but in parallel, they also intend to increase their contribution to energy consumption by a similar percentage. In the end, percentages stay the same, but contamination increases several fold as per an expansion of energy use, in a context of already dire conditions for climate forecasts. That's simply unsustainable.

What we should see instead, is the steady transfer of energy consumption from fossil fuels to renewable over the next 50 years, progressively phasing out the quantitative amount of fossil fuels consumed at a global scale.

This brings us to the present discussion around unconventional types of fossil fuels, such as shale gas, through processes such as hydraulic fracturing (or fracking). Fracking is a response to the drying up of conventional petroleum wells, and the need to extract more and more fossil fuel from our Earth. We couldn't do it before because the numbers and the economics for fracking didn't add up. With recent technological advances, those numbers have changed. We can now extract fuel not from massive wells, but from the pours or rock, and still make a profit. That extends the life of oil extraction indefinitely as long as we can tap the hard to get to oil and gas.

We oppose the industry shift towards this type of fossil fuel production not merely because we are concerned with the many environmental risks and impacts caused by fracking, but most importantly, because a shift to fracking *is not* addressing the much greater and severe climate challenges we are facing as a global society. We need less oil and gas production and not more. We would prefer to see national investments going to fracking activity invested in expanding research, technology and production for the production and efficiency improvement of renewable energies.

But this report is NOT an "anti fracking" report. It is also NOT a report about the tradeoffs of fracking vs. other energy sector investments. Our objective in writing this report is not to oppose fracking, but to lay out the basic fundamentals of fracking for the non-expert, including reflecting on the basic environmental risks and impacts caused by fracking, so that we can have an objective debate about the fracking processes and what we might have to face from an environmental standpoint if we decide to move forward with shale gas extraction in Argentina.

The national government of Argentina recently and forcefully took over a private petroleum company, Repsol YPF, following an enormous shale gas deposit discovery at Vaca Muerta, a region of the Southern Patagonia region (Neuquen Argentina). The politics of this decision is clear. The government is behind the decision to expand fracking and shale gas extraction. It has become national policy.

In the midst of recurring energy crisis, where the government systematically fails to provide energy solutions to Argentina's energy consumption needs, and where there is currently no national renewable energy promotion strategy, the extraction of non-conventional gas deposits today represents a very significant proposal to address a significant portion of Argentina's energy consumption needs.

Yet this proposal is countered by serious barriers to such a strategy, including the long standing absence of investments in the petroleum sector. Once in the past, the original State-owned YPF company provided a learning platform to a once non-existent petroleum sector in neighboring Brazil. Petrobras staff learned from YPF staff how to explore for and extract oil. But years of investments in the Brazilian company, and years of abandonment in the Argentine company, as well as strong energy policy in one country and no energy policy in the other, have now developed into two very different petroleum players, one aggressive and growing, and the other in crisis.

Shale gas offers the Argentine government a platform upon which to build an energy future, but past political inconsistencies, poor management, and very poor government national policy, have not shown to the Argentine population, the capacity of the public sector to build a vibrant, efficient and lawful energy sector. YPF has been riddled with failure, spills, and inefficiently, which today does not bode well for those concerned that shale gas extraction will bring the same inefficient and poor policy.

When we look at the experience of industrialized countries like the United States, with fracking, and see the very serious environmental contamination that comes with hydraulic fracturing, we can only be reassured that this impact will come in even worse scenarios in Argentina, where federal and local State environmental controls are weak or non-existent. Today, the intromission of inexperienced high level public officials, into the day to day technical operations of YPF, are proof that Argentina's new energy policy has been hastily devised and not strategically oriented on sound foundations. We are concerned that the nationalization of YPF and the bet on fracking is just one more of these overnight policy decisions that will only bring further troubles to an already shaky sector.

We try in this report not to transpose our opposition to fracking in Argentina, which we would also like to make public, to what we hope will offer a neutral look at the fracking process, so that we may lay out the key issues and areas of concerns to address eventual social and environmental impacts of the fracking process.

The content of the report was researched by CEDHA staff and comes thanks to Anna Roeloffs and Candace Headen, who contributed the initial research and drafting of this report. It is a compilation of academic and professional material easily available online.

We have tried to provide as neutral a look as possible into the particularities of fracking, to help inform communities and concerned citizens, but also to help establish communication with policy makers and company representatives, so that we can also engage on a constructive discussion about fracking and its implications for the environment and people in Argentina.

In the case of Vaca Muerta, in Neuquén province, indigenous populations reside in the project area. Recent international laws (such as ILO Convention 169, guaranteeing the rights of indigenous peoples to participate and to be consulted on development projects in their area) have laid out a new framework for engagement with indigenous communities . Argentina ratified Convention 169 in the year 2000. It is still to be seen how the government will seek indigenous peoples support for shale gas extraction in the area.

We hope this report will provide a useful platform as a backdrop for future exchanges on fracking techniques and the sector more generally in Argentina and elsewhere. We also encourage feedback on the report, and any information that helps clarify, correct or expand its content.

BACKGROUND ON FRACKING AND NATURAL GAS EXTRACTION

WHERE DOES NATURAL GAS COME FROM?

Natural gas consists of gaseous hydrocarbons (predominantly methane, CH_4, besides other alkenes C_nH_{2n+2}), and may also contain other gases such as hydrogen sulfide, nitrogen, carbon dioxide. There are two types of natural gas (methane):

1. thermogenic methane: Conversion of organic material contained in rock under the action of heat (Coalification)
2. biogenic methane: Activity of microorganisms contained in rock, which decomposes organic residues and produces methane.

Most methane is constantly migrating from inside the Earth, through porous rock layers on route to the surface, and then released into the atmosphere. If on this path, the gas reaches an impermeable layer, the gas can be contained in *gas traps* and held in *reservoir rock*, forming what are called *conventional* natural gas deposits.

A portion of this methane remains at its place of origin, or *source rock*. These gas source rocks may be, for example, clay or shale, which are both rich in organic matter, or coal. The accumulation of natural gas in such rocks is called *unconventional* natural gas deposits (GD NRW 2012).

WHAT IS THE DIFFERENCE BETWEEN CONVENTIONAL AND UNCONVENTIONAL RESERVOIRS?

Hydrocarbons – including natural gas and crude oil – were formed from organic matter over hundreds of millions of years ago. In an anaerobic setting the organic matter was buried, decomposed and converted into petroleum (natural gas or crude oil) under the influence of temperature and pressure (Suárez 2012).

Natural gas migrates through porous rocks until it reaches an impermeable layer and accumulates in various types of geological traps (Suárez 2012). The general classification of gas reservoirs can be divided into two types:

- ***Conventional reservoirs*** (source) are characterized by a limited area within porous rocks which are sealed by impermeable rocks (seal). The seal avoids the escape of the gas to the surface. For the recovery process, wells are drilled into the reservoir (Fig. 1). The compressed gas expands through the wells in a controlled manner. At the surface it is captured, treated and transported. The recovery factor of the expansion process can reach up to 80% of the primary gas in place (Suárez 2012).
- ***Unconventional reservoirs*** are characterized by sedimentary layers with low permeability which are packed with natural gas. Advanced technologies such as artificial stimulation (Fracking) are needed to recover this gas in a way that is economically feasible. Unconventional reservoirs of gas include shale gas, tight gas, coal bed methane and gas hydrates (Suárez 2012).

TYPES OF UNCONVENTIONAL RESERVOIRS

Natural gas production of unconventional reservoirs is only partly limited to traps or geological structures. Therefore it can expand into large geographical areas (Suárez 2012).

SHALE GAS

Shale Gas refers to natural gas that is produced from reservoirs composed of shale. Shale is a fine-grained sedimentary rock which breaks into thin, parallel layers and has a low permeability. Because of this low permeability an economical production requires fractures to provide permeability (Suárez 2012; Stevens 2010).

TIGHT GAS

Tight Gas is natural gas that is produced from reservoirs of certain sandstone and limestone with low porosity and low permeability. The standard definition for tight gas reservoirs describes a rock with a matrix porosity of less than 10% and permeability of less than 0.1millidarcy. To produce this type of gas economically, locating areas and drilling wells are situated where natural fractures are present. Additionally, almost all tight gas reservoirs must be artificially fractured (Suárez 2012, Stevens 2010).

Coal Bed Methane (CBM)

Coal Bed Methane (CBM) is located in coal deposits underground and contains a high percentage of methane. In a CBM gas reservoir, water pervades coal beds. The methane is absorbed onto the grain surface of the coal due to pressure. For production of CBM, the water must fist be removed. When the pressure is lowered, the methane separates from the coal and flows into the well bore. Gas production increases with lower water content. But coal beds have low permeability and need artificial stimulation for production to be economical, for instance, with hydraulic fracturing (Suárez 2012, Stevens 2010).

Gas Hydrates

Gas hydrates is natural gas which is trapped in ice crystals in permafrost and on ocean floor regions. The amount of natural gas captured in hydrates is estimated to be larger than all other sources of natural gas combined, but its production is not yet cost efficient with today's available technology (IEA 2009).

What production techniques are available?

In order to use unconventional gas reserves, it is necessary to create a pathway to extract the gas from the reserve. Available extraction techniques are highly dependent on the type of deposit present (shale gas / coal bed methane/ tight gas), and according to the rocks and mineralogical composition, existing fractures, layer thicknesses and/or storage conditions as well as other factors (GD NRW 2012).

What is Fracking?

The Process

Hydraulic fracturing (also known as fracking) is a method used to create fractures that extend from the well bore into rock or coal formations (Suárez 2012). These fractures allow the oil or gas contained in the rock to migrate from rock pores, where the oil or gas is trapped, to the production well (Fig. 2). To access this natural gas, vertical wells are drilled and highly pressurized water, sand, and fracking fluids are pumped into the rock at high pressure. This highly pressured water induces pressure fractures in the rock and the existing micro-cracks can be extended by a few millimeters. Sand (or quartz powder) is injected into the cracks to subsequently hold them open allowing the gas to exit. The crack surfaces achieved can be a few hundred meters in length and can reach several tens of meters in height. The propagation of cracks is monitored by seismo-acoustic techniques and can be controlled by variation of water pressure. Chemicals are used to assist the injection process into the cracks. The natural gas then flows into the well (Fig.3). This process provides access to previously inaccessible sources of natural gas (GD NRW 2012).

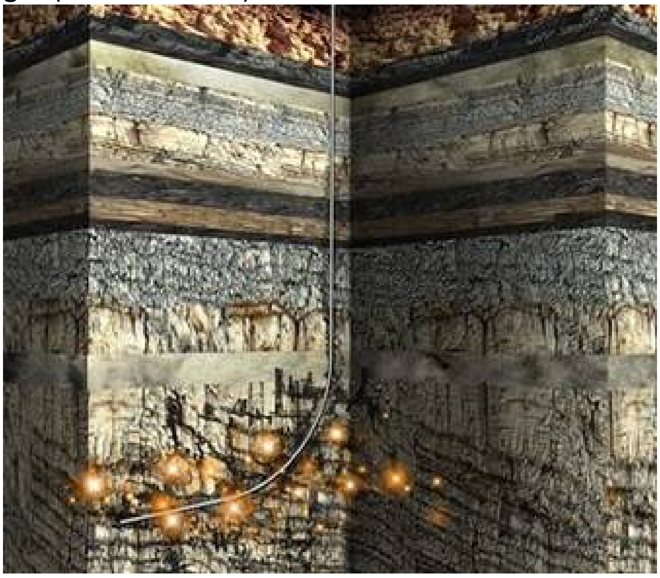

Figure 2: Fracted strata (GD NRW 2012)

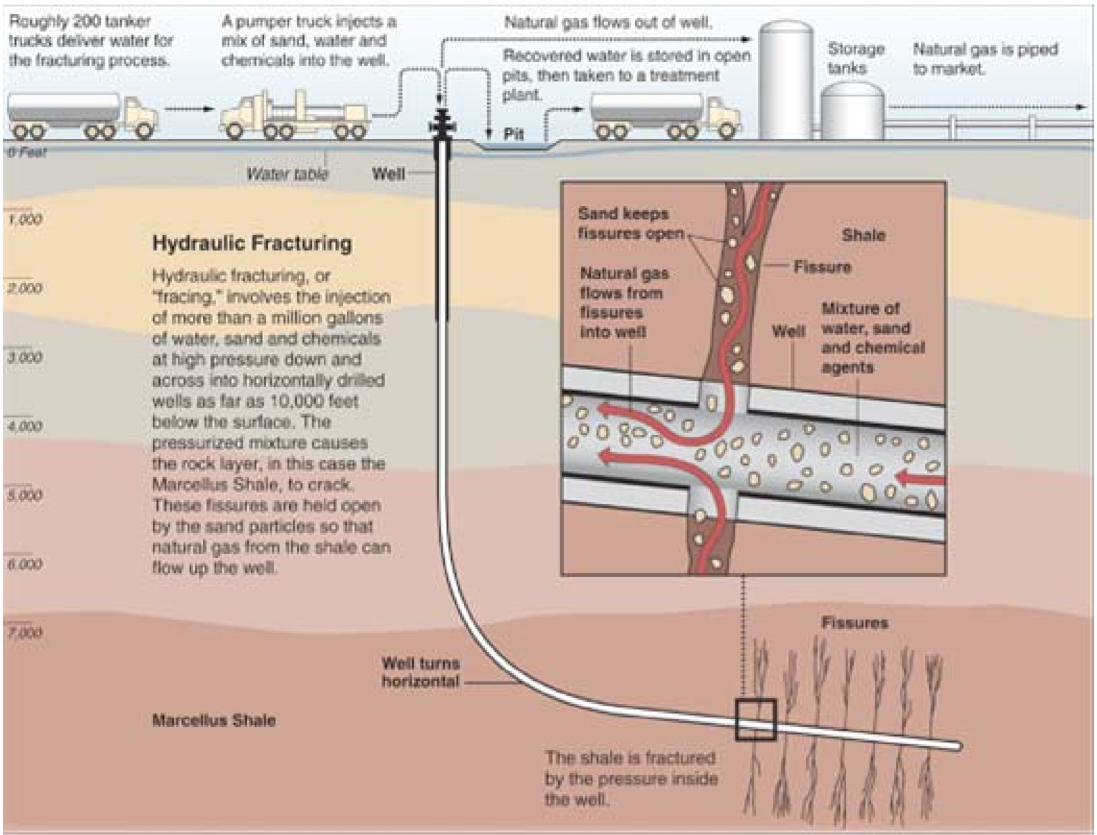

Figure 3. This image depicts the many stages of the hydraulic fracturing process (Summit County Voice 2011).

Vertical Drilling and Hydraulic Fracturing

Hydraulic fracturing was first used in the late 1940s, and has since become a common technique to enhance the production of low permeability formations, especially unconventional reservoirs such as tight sands, coal beds, and deep shales (GWPC 2012: 21). Originally, vertical fracturing provided access to a fairly limited amount of natural gas – wells could only harvest from the area directly underneath them. However, the advent of horizontal fracturing brought with it great opportunity to harvest previously inconceivable quantities of shale gas. By using horizontally fracturing, a single well can produce not only the gas that rests immediately below it, but also the gas surrounding the well, making far more profitable.

Horizontal Drilling and Hydraulic Fracturing

The first horizontally drilled wells were drilled in Texas in the 1930's. By the 1980's horizontal drilling became a standard industry technique. The shift to shale gas extraction was in part due to the reduction of surface locations in urban areas. Horizontal wells can reduce the number of wells needed to developing a gas field. As Suárez notes, through horizontal drilling, you significantly reduce the overall number of well pads, access roads, pipeline routes, and production facilities required to extract the gas. (Suárez 2012: 8).

Drilling a well is a highly involved process that employs a combination of chemicals used to increase the density and weight of fluids to facilitate drilling, reduce friction, shorten drilling time, reduce accidents, and return debris to the surface (Colborn 2011: 1040). As with most drilling projects, an important quantity of water is needed in the process. Wells are lined with cement to prevent natural gas from seeping out on its way to the surface or into groundwater aquifers.

The natural gas that is extracted from a well is generally mixed with water and various other compounds, including benzene, toluene, ethylbenzene, and xylene (collectively called BTEX) and hydrogen sulfide (Colborn 2011: 25). These compounds must be removed before the gas can be usable (Colborn 2011: 25). To accomplish this task, the gas mixture is passed through heater treaters, tanks filled with triethylene glycol and/or ethylene glycol (Colborn 2011: 25). These compounds absorb some of the water that accompanies the natural gas out of the well (Colborn 2011: 25). The unit is then heated and the water boils off and is vented into a separate tank labeled *produced water* (Colborn 2011). During this process, oily substances that were mixed in with the gas become volatile and are siphoned off into a different holding tank and labeled *condensate water* (Colborn 2011). In the United States, these byproducts—*produced and condensate water*—are held in reserve pits during the drilling process (Colborn 2011: 25). Once drilling has concluded, they are commonly re-injected to the ground or taken to waste evaporation pits. Additionally, produced water can be treated and recycled or treated and disposed of (Nicholson & Blanson 2011).

Fracking Fluid

Fracking fluid is a term used to describe the liquid used in the hydraulic fracturing process. This fluid is mostly comprised of water—about 98-99.5% (GWPC 2009). This water is mixed with a cocktail of between three and twelve different compounds to form fracking fluid (GWPC 2009). A unique combination of fluids is created for every well to accommodate the distinct geology of each area (GWPC 2009). Below is a chart detailing the categories of compounds used, their purpose, and common forms of each (GWPC 2009, GD NRW 2012) (Tab. 1):

Compound Category	Purpose	Example
Surfactants / wetting agents (surfactants)	Reducing the surface tension of the fluids, Increases viscosity	Isopropanol
Salt	Creates a brine carrier fluid	Potassium chloride
Gelator (Gelling Agent)	Improvement of the proppant transport	Guar gum, hyrdoxyethyl cellulose
Deposition inhibitors (scale inhibitor)	Preventing the deposition of sparingly soluble precipitates, such as carbonates and sulfates	Ethylene glycol
pH regulators and buffers (pH control)	Maintains effectiveness of other components	Sodium or potassium carbonate
Chain Breaker (Breaker)	Reducing the viscosity of gel-containing Frack fluids to deposit the proppant	Ammonium persulfate
Crosslinker	Maintains fluid viscosity with temperature increases	Borate salts
Iron precipitation control (Iron Control)	Prevention of iron oxide precipitates	Citric acid
Corrosion inhibitor	Prevents pipe corrosion	n,n-dimethyl formamide
Biocide	Prevention of bacterial growth, prevention of biofilm, preventing formation of hydrogen sulfide by sulfate-reducing bacteria	Glutaraldehyde
Acids	Preparation and cleaning of the perforated portions of the drilling mud and cement; resolution of acid-soluble minerals	Hydrochloric acid or muriatic acid
Friction reducer (slickwater additives)	Reducing friction within the Frack fluids, Allows fracking fluid to be pumped at faster rates and lower pressures	Polycrylamide, mineral oil
Oxygen scavenger	Removes oxygen to protect from corrosion	Ammonium bisulfate
Support means (proppant)	Props the fractures open to allow the gas to escape	Silica, quartz sand
High temperature stabilizer (Temperature Stabilizer)	Prevention of premature decomposition of the gel at a high temperature in the	

	target horizon	
Solvent	Improving the solubility of the additives	
Foams (Foam)	Support of the proppant transport	
Hydrogen sulfide scavenger (H_2S Scavenger)	Removal of hydrogen sulphide to prevent system corrosion	
Clay stabilizers	Reduce swelling and displacement of clays	

After the fracking process, generally between ten and ninety percent of fracking fluid can be recovered, depending on a number of circumstances (Colborn 2011: 25). The fracking fluid that is not recovered remains in the ground (Colborn 2011: 25).

The Economics

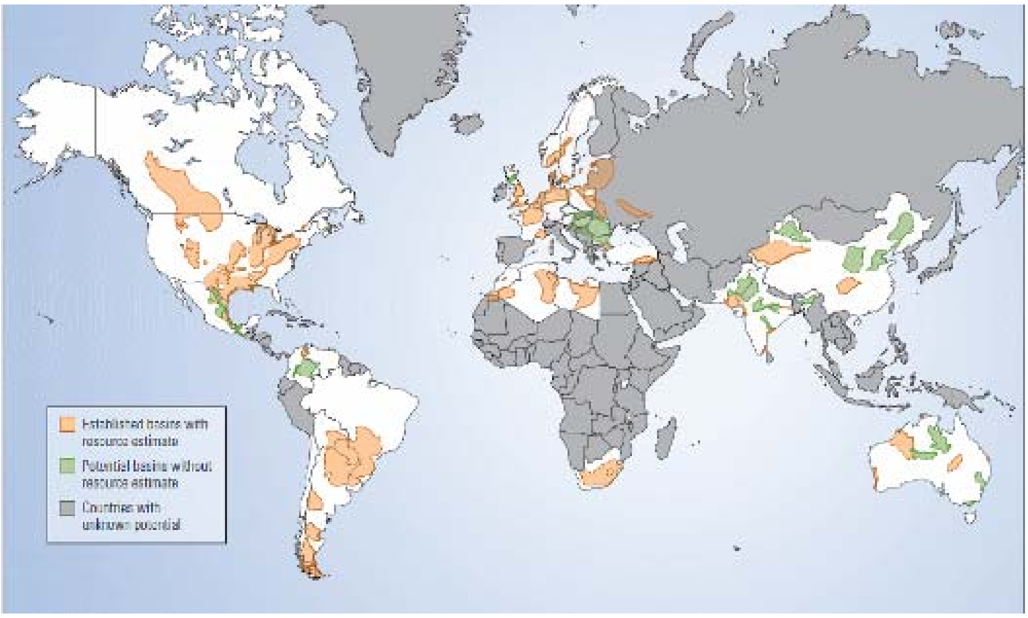

Figure 4: Global shale gas resources (Kuuskraa et al. 2011).

Producing commercial quantities of natural gas from unconventional organic-rich shales was unique a decade ago. Petroleum companies all over the world, including South America, Africa, Australia, Europe and Asia, are analyzing seismic data, drilling exploratory wells and geological formation for gas production capabilities (Fig. 4). In the US the main developers of exploration techniques have generally been smaller operators. By contrast, in Europe large multinational energy companies tend to dominate the unconventional gas sector. Major companies involved include Exxon Mobil Corporation, Total S.A., ConocoPhillips Company and Marathon Company.

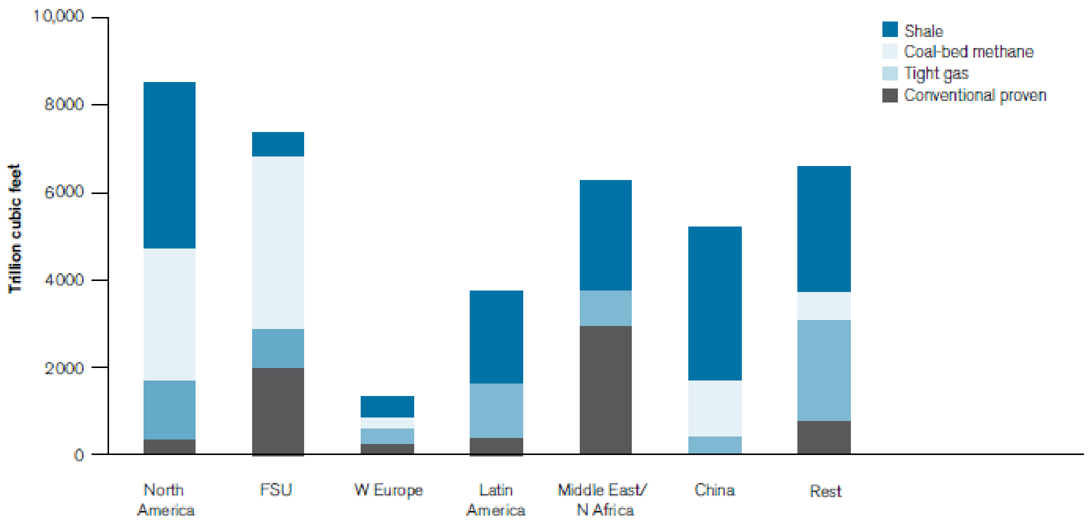

Figure 5: Estimates of global unconventional gas reserves (BP 2008)

In 1997 global shale gas reserves were estimated at 16.112 Tcf (456 trillion m^3). 2011 EIA corrected the study to 25.300 Tcf (416 trillion m^3) (Fig.5) (Tab. 2).

Region	1997 Rogner Study (Tcf)	2011 EIA Study (Tcf)
North America	3.842	7.140
Asia	3.528	5.661
South America	2.117	4.569
Africa	1.548	3.962
Europe	549	2.587
Australia	2.313	1.381
Other	2.215	Not available
Total	16.112	25.300

Environmental Risks of Fracking

Experience in the U.S., where the production of unconventional gas reservoirs occurs on a large scale, has revealed numerous environmental impacts associated with the implementation of fracking-technology (Zittel 2010).

One of the more common complaints from communities in drilling areas are associated to noise and exhaust fumes from the production process. Other complaints are associated to infrastructure introduction, heavy transport, and water connumption as well as contamination.

Methane release in the process is another key environmental risk associated to fracking, which has been the focus of several environmental groups. Seismic activity has also been reported in relation to fracking, that is, the frack-process could trigger earthquakes. The release of radioactivity and other pollutants such as mercury are also associated to natural gas production (GD NRW 2012).

ENVIRONMENTAL IMPACTS

WATER

Large quantities of water are required for drilling and completion of wells. Vertical and horizontal drilling of a well requires 400–4000 m^3 of water for drilling fluids to maintain downhole hydrostatic pressure, to cool the drillhead, and remove drill cuttings (Gregory et al. 2011). Drilling holes may involve penetrating groundwater aquifers. The cemented casing introduced in the drill hole - a cement seal between rock and metal pipe over the entire borehole length – is intended to ensure that there is no contact between the borehole and aquifers (GD NRW 2012: 17).

During the actual fracking-process, fracking fluid injected into the rock can escape into groundwater layers through natural fractures in the rock (GD NRW 2012: 17). For this reason, it is important to properly study natural rock faults in exploration areas as well as conduct seismic studies to reduce exposure of ground water to contaminating fracking fluids (GD NRW 2012).

If faults occur in the well design and construction, this can lead to cracks in the cement casing, allowing gas and other chemicals to infiltrate aquifers, ground water, and other nearby water sources. Many in the hydraulic fracturing industry claim that poor well construction is to blame for the environmental problems associated with fracking. In coal mining areas local methane leaks can occur and migrate to the surface (Meiners 2001; Thielemann 2000).

Fracking can also reduce the quality and quantity of water available for community consumption. Each well utilizes millions of gallons of water, greatly diminishing citizen-used water tables (Nicholson & Blanson 2011). For each well of hydraulic fracturing 7.000–18.000m^3 of water are needed (Gregory et al. 2011).

MANAGEMENT OF FLOWBACK WATER

Another impact of fracking involved *flowback* water which is water that is expelled from the remnant process and which can occur for a period of a few days to a few weeks after the extraction. The quantity of flowback depends on geology and geomechanics of the formation in question. The composition of the flowback water fluids changes over time but the principal components are in a brine solution including salts, metals, oils, greases, and soluble organic compounds, both volatile and semivolatile. The following treatment technologies and management strategies are established to deal with flowback:

1. Underground Injection:
   Most produced water from oil and gas production in the United States is disposed of through deep underground injection (Clark & Veil 2009). But shale gas development is currently occurring in many areas where insufficient disposal wells are available to dispose of waste water. The construction of new disposal wells is complex, time consuming, and costly (Arthur et al. 2008). As a result, other solutions for flowback water management are necessary (Gregory et al. 2011).
2. Discharge to Publicly Owned Treatment Works (POTWs) for Dilution Disposal:
   The discharge and dilution of flowback water into publicly owned municipal wastewater treatment plants has not offered a sustainable solution. The amount of high-TDS flowback water that can be handled per day is too small for adequate treatment.
3. Reverse Osmosis (RO):
   In the RO process, water is passed through a semi permeable membrane under pressure and drinking water and high-purity industrial water is produced, along with a concentrate that requires disposal (Gregory et al. 2011). The volume of concentrate for disposal has been reduced to as low as 20% of the initial volume of flowback water (ALL Consulting 2003). RO is an energy-intensive process which poses significant energy availability questions. The treatmentof flowback water using RO is considered not to be economically feasible for waters containing more than 40,000 mg/L TDS (Cline et al. 2009).
4. Thermal Distillation and Crystallization:
   The high concentrations of TDS in flowback water can be treated by distillation and crystallization (Doran and Leong 2000). Waste water is evaporated to separate the water from its dissolved constituents, but the process is very energy-intensive, as with RO.
5. Other Treatment Options:
   Several other technologies are “ion exchange and capacitive deionization (Jurenka 2007), which are limited to the treatment of low-TDS water; freeze–thaw evaporation, which is restricted to cold climates; evaporation ponds, which are restricted to arid climates; and artificial wetlands and agricultural reuse (Veil et al. 2004), which are greatly limited by the salinity tolerance of plant and animal life” (Gregory et al. 2011: 185).
6. On-Site Reuse for Hydraulic Fracturing:
   Another technology for the management of flowback water is its reuse in hydraulic fracturing operations. The benefit is that the volume of water is minimized and the environmental risks are reduced.

Land

Most byproducts of the hydraulic fracturing process are held in open evaporation pits near the well site (Colborn 2011: 25). These pits can be home to extremely toxic chemicals (Colborn 2011: 25). The chemicals are drained after a well is closed, but residue remains at the site, generating serious land contamination and future land use limitations and challenges. (Colborn 2011: 25).[1]

Furthermore, flowback and produced water (and the chemicals contained within them) can be improperly disposed of, polluting domestic and agricultural water supplies (Nicholson & Blanson 2011).

Air

According to a study conducted by The Endocrine Disruption Exchange (TEDX), the fracking process produces a number of environmental atmospheric concerns (Colborn 2011: 1042). Toxic volatile compounds like BETX, other hydrocarbons, and methane can escape at some stages of hydraulic fracturing (Colborn 2011: 1042). These compounds mix with the nitrogen oxides produced by the exhaust of diesel-fueled fracking equipment to form ground-level ozone (Colborn 2011: 1042). If inhaled, ground-level ozone can burn alveolar lung tissue, causing premature aging and chronic exposure often leads to the development of asthma and chronic obstructive pulmonary disease (COPD) (Colborn 2011: 1042). If this ozone combines with particulate matter in the air, it creates haze, a phenomenon that has proven detrimental to human health as evidenced by increased emergency room visits during periods of elevation (Colborn 2011: 1042).

Other Natural Resources

The ground-level ozone that can be produced by the hydraulic fracturing process has the potential to damage a number of plant species, including conifers, aspen, forage, and alfalfa.

Seismic Activity

During Fracking water is pressed under high pressure into the rock. The ripping of fractures always occurs in breaking-processes that are measurable, as micro-earthquakes. This can occur under certain geological conditions (such as in the presence of brittle rocks with tectonic discontinuities, which are under tension). Sensors are established to monitor Fracking seimic impacts.

[1] Under CERCLA, an “eligible response site” is generally defined as a brownfield site, which is “real property, the expansion, redevelopment, or reuse of which may be complicated by the presence or potential presence of a hazardous substance, pollutant, or contaminant.” 42 U.S.C. § 9601(39)(A), (41)(A) (2006).

COMMUNITY EFFECTS

HEALTH EFFECTS

Compounds used in fracking fluid can be detrimental to human health (Colborn 2011: 1039). Perhaps even more concerning is that many of these health effects do not immediately become manifest (Colborn 2011: 1039). Below is a table listing some harmful components found in fracking fluid and their potential health effects (What is fracking 2012a).

COMPOUND	POTENTIAL HEALTH EFFECTS
Crystalline Silica*	Silicosis and cancer
Methanol*	Eye irritation/damage, headache, fatigue, death
Isopropanol*	Eye irritation, respiratory irritation, drunkenness, vomiting
Hydrotreated light distillate*	Skin irritation, eye irritation, headache, dizziness, liver damage, kidney damage, blood damage
2-Butoxyethanol*	Eye irritation, nose irritation, headache, nausea, vomiting, dizziness
Ethylene glycol*	Stupor, coma, fatal kidney injury
Diesel*	Skin redness, itching, burning, severe skin damage, skin cancer
Sodium hydroxide (lye)*	Lung damage, eye burning, skin burning, mucous membranes burning, death
Naphthalene*	Respiratory tract irritation, nausea, vomiting, abdominal pain, fever, cancer, death
Formaldehyde	Lung damage, reproductive problems in women, cancer, death
Sulfuric acid	Corrosive to all body tissues, lung damage, loss of vision, cancer, death
Benzene	Dizziness, weakness, headache, breathlessness, chest constriction, nausea, vomiting, bone marrow failure, leukemia, cancer
Lead	Nervous system damage, brain disorders, blood disorders, cancer
Boric acid	Kidney damage, kidney failure
Fuel oil #2	Dizziness, drowsiness, eye irritation, skin irritation, skin cancer

Kerosene	Eye irritation, nose irritation, drowsiness, convulsions, coma, death
Hydrofluoric acid	Hardening of bones, burns, corrosion of body tissues, irritation, death
Hydrochloric acid	Corrosive to tissues, eye irritation, respiratory problems, death
Formic acid	Skin burns, eye burns, lung irritation and pain, nausea, vomiting

* most commonly found components (What is fracking 2012a)

Industry representatives generally argue that the hydraulic fracturing process generally uses small and insignificant concentrations of chemicals, and suggest that they are harmless to human health. However, as a study conducted by TEDX explains, most of these chemicals should not be ingested at *any* concentration (Colbron 2009: 1049).

In many cases impacts may not be immediately noticeable and may manifest in extended periods, having impacts directly on contaminated individuals and/ their offspring" (Colbron 2009: 1049). Furthermore, it is difficult to predict the potential health effects of the combination of various chemical compounds within the body—especially if they are affecting the same organ systems (Colbron 2009: 1049).

Variables that may be determinant in effects of impacts are proximity of contact to fracking sites, and process and form of exposure. A study by McKenzie (2012) shows that residents living ≤½ mile from wells are at greater risk for health effects from natural gas development than are residents living >½ mile from wells. "Subchronic exposures to air pollutants during well completion activities present the greatest risk of health impacts. The subchronic non-cancer hazard index (HI) of 5 for residents ≤½ mile from wells was driven primarily by exposure to trimethylbenzenes, xylenes, and aliphatic hydrocarbons" (McKenzie 2012: 1).

As chemicals are used in both the well development and hydraulic fracturing process alike, health concerns exist at every stage of the process (Colbron 2009: 1053). Often, people living near fracking sites begin to feel symptoms before any fracking has actually occurred (Colbron 2009: 1053).

Radioactivity

There are no data on significantly elevated levels of radioactivity in rocks used by hydraulic fracturing. An exception exists in relation to hydrothermal mineralization in coal mines. The increased radionuclide cargo of the mine water is probably related to the occurrence of barium minerals (barite) (GD NRW 2012).

MURCERY IN COALBED METHANE

It has long been known that natural gas contains gaseous mercury. This depends crucially on the source rock from which natural gas was generated. Some coals contain a low amount of gaseous mercury, other rocks, f.e. “Red-Bed”-rocks from the Permain, Peckensen, Germany, contain an increased volume of mercury, which needs treatment during production (GD NRW 2012).

CONFLICTS SURROUNDING FRACKING OPERATIONS

UNITED STATES

Currently, the only commercial shale resource plays are located in North America (Boyer et al. 2011). Groundwater Protection Council (GWPC) is the supervisory authority concerning questions on fracking in the United States. One problem in America is that local states have their own regulation, when it comes to fracking. Some states have strict requirements, others do not.

PENNSYLVANIA

In 2009, *Zimmerman v. Atlas America* marked one of the first fracking cases in the United States (Nicholson & Blanson 2011). The Zimmermans and Atlas America, LLC (“Atlas”) entered into a contract that gave the company the rights to conduct hydraulic fracturing on their farm, leaving the family with only the surface rights to their property (Nicholson & Blanson 2011). After drilling commenced, the Zimmermans alleged that Atlas was using toxic chemicals that were polluting their water sources and destroying their heirloom tomato farm (Nicholson & Blanson 2011). They eventually sued the company, alleging trespass, nuisance, negligence, negligence per se, *res ipsa loquitor*, fraud and misrepresentation, and breach in addition to violation of state law (Nicholson & Blanson 2011).

Shortly after the *Zimmerman* case, nineteen families filed suit against Cabot Oil & Gas Corporation (“Cabot”) for state law violations and negligence, gross negligence, negligence per se, nuisance, strict liability, fraudulent misrepresentation, breach of contract, and medical monitoring trust fund under *Fiorentino v. Cabot Oil & Gas Corporation* (Nicholson & Blanson 2011). The plaintiffs in the case alleged that Cabot “allowed excessive pressure to build up within gas wells near the plaintiffs’ homes and water wells, resulting in an explosion; spilled diesel fuel onto the ground near their homes and water wells; discharged drilling mud into diversion ditches; and caused three significant spills within a ten-day period”(Nicholson & Blanson 2011). The Pennsylvania Department of Environmental Protection (the “Department”) also initiated action against Cabot on behalf or Pennsylvanians whose wells the company allegedly contaminated with methane as a result of fracking. This case was eventually settled, and the families represented received a collective $4.1 million and Cabot paid a $500,000 fine to the Department. While the families were allowed to maintain their preexisting *Fiorentino* law suit, Cabot was also allowed to resume hydraulic fracturing (Nicholson & Blanson 2011).

In 2010, thirteen families filed suit against Southwestern Energy Production Company ("Southwestern") in *Berish v. Southwestern Energy Production Company, et. al.* The plaintiffs in this case claimed that Southwestern had drilled close to their water wells and that, because the wells were improperly cased, contaminants had entered their wells. At least one of these plaintiffs has demonstrated neurological symptoms indicating exposure to heavy metals. The *Berish* case alleges negligence per se, common law negligence, nuisance, strict liability, medical monitoring trust fund, and violation of state law. The plaintiffs also allege trespass, claiming that Southwestern exceeded its permission to be on the land by allegedly causing water contamination (Nicholson & Blanson 2011).

Armstrong v. Chesapeake Appalachia alleges many of the same causes of action as the *Fiorentino* and *Berish* cases. The plaintiffs allege that Chesapeake Appalachia LLC and two other companies employed a defective cement casing in their fracking wells, leading to the discharge of methane, ethane, barium and other substances in their personal wells about three miles away (Nicholson & Blanson 2011).

Texas

The State of Texas has seen extensive fracking and has also been the target of much fracking-related legal action in recent years. The Scoma family sued Chesapeake Energy Corporation and two related companies (collectively "Chesapeake") in regards to their fracking activities under *Scoma v. Chesapeake Energy Corporation, et. al.* Chesapeake, the plaintiffs allege, stored drilling waste and disposed of fracturing waste near the Scoma's property (Nicholson & Blanson 2011).

Europe

France

In France, grounded on unpredictable environmental damage that may be caused by fracking, fracking has been banned since October 2011.

Germany

Since 1961 hydraulic fracturing is used to improve the productivity of hydrocarbon drilling as well as geothermal wells in the Lower Saxony, Germany. But it is also used for production of drinking water and remediation of contaminated sites. In geothermal a technically similar method is applied to improve the properties of the deposit (stimulation), but the working fluid includes only water without chemical additives.

In 1995 Coal bed methane drilling Natorp 1 in Warendorf, North Rhine-Westphalia, Germany was performed. In October 2009 an announcement of former Prime Minister of Lower Saxony, Christian Wulff, was made that the company ExxonMobil will search for unconventional natural gas in Lower Saxony, Germany. Further interested companies are Winterhall, RWE Dea AG, Evonik, Thyssengas, BNK Pertroleum, BEB Erdöl und Erdgas GmbH, GDF Suez E&P Deutschland GmbH.

At the 22 of April 2010 the magazine "Der Spiegel" published an article titled Natural Gas – Resource Hunters can dream of Production-Boom (www.spiegel.de, 22.04.2010). At 18. of November 2010 the film "Gasland" by Josh Fox shows the probable consequences of fracking methods used in the United States.

Since early 2011, Germany has seen many public protests against fracking in the North-Rhine Westfalia and citizen initiatives were founded.

In November of 2011, a Moratorium in North-Rhine Westphalia and other states of Germany was issued suspending all applications for unconventional gas production until proper studies are conducted by the Federal Government concerning the risks of fracking to humans and nature. A study commissioned by the Federal Government published in September of 2012, states that fracking is risky because of chemical additives used.

Experts recommend utilizing less onerous fracking additives, such as mixtures with highly toxic, carcinogenic and mutagenic properties. Other concerns over the disposal of contaminated water and debris, led the government of North Rhine-Westphalia, Germany to prohibit fracking drilling.

In other German states fracking can take place under strict conditions and outside of groundwater protection areas.

AUSTRALIA

In 2012 Australia imposed a moratorium on fracking, following farmer protests against the activity.

FRACKING IN ARGENTINA

Argentina has the largest resource potential with an estimated 77 trillion m³ [2.732 Tcf] of GIP. 21.9 trillion m³ [774Tcf] are considered technically recoverable (Boyer et al. 2011).

Figure 5: South America Shale basins (Boyer et al. 2011)

Neuquén Basin

The Neuquén Basin is located in central west area of Argentina and seems to have the greatest potential for shale gas development. Oil and gas is already produced in the region from conventional and tight sandstones. Important formations are the middle Jurassic Los Molles Formation and the early Cretaceous Vaca Muerta Formation. Both contain organic-rich sediments. The Vaca Muerte Formation is situated in a moderate depth of 2440 m, in overpressured conditions and with a high average of total organic carbon (TOC). Before it was nationalized, the YPF oil company announced in May of 2011 that it had discovered 150 million barrels of shale oil in Vaca Muerta, an oil field in the Patagonia region (Krauss 2011). Since then, 22.8 billion barrels of oil equivalent have been proven, giving Argentina the third largest recoverable natural gas reserves in the world (Fontevecchia 2012). President Cristina Fernandez de Kirchner has declared "hydrocarbon self-sufficiency" to be "in the national interest", leading to the nationalization of YPF and the acceleration of hydraulic fracturing preparation within

Vaca Muerta. The Los Molles Formation generates less net GIP but has richer sections with TOCs averaging 2% to 3%.

San Jorge Basin

San Jorge Basin bears 30% of Argentina's conventional oil and gas production. Important formations are the Late Jurassic and Early Cretaceous Aguada Bandera Shale (source rock) with good thermal maturity and middle to high TOCs. Its depth is located by 3.487 and 3.706m. Another important formation is the Early Cretaceous Pozo D-129 shale because of its thickness of 915m, its moderate TOC and good thermal maturity.

Austral-Magallanes Basin

In the South of Patagonia one can find the Austral-Magallanes Basin with its organic-rich source rock from the lower Cretaceous lower Inoceramus Formation. The formation is 200m thick and found at depth of 2.000 to 3.000m. The TOC values are medium to low.

Chaco-Paraná Basin

The Chaco-Paraná Basin is situated in the North of Argentina and covers an area of 1.294.994 km². Devonain-age Los Monos Formation contains the San Alfredo Shale. This Shale can reach a thickness of organic-rich sections of 600m. Up to the moment the Chaco-Paraná Basin has not been extensively explored.

Major Companies in Argentina

YPF S.A.	Neuquén Basin
Apache Corporation	Neuquén Basin
Wintershall Energia S.A.	Neuquén Basin
Total Austral S.A.	Neuquén Basin
PanAmerican Energy	Neuquén Basin
ExxonMobil	Neuquén Basin
Shell	Chaco-Paraná Basin
Americas Petrogas Inc.	Neuquén Basin
Bridas Corporation	Neuquén Basin
Enarsa	Neuquén Basin
Petrobras Argentina	Neuquén Basin
EOG Resources	Neuquén Basin

Chevron	Neuquén Basin
Apache	Neuquén Basin

THE FUTURE OF FRACKING IN ARGENTINA?

Many issues related to the unconventional gas resources in Argentina are still unanswered and must be addressed before the extraction of unconventional gas reservoir in Argentina occurs. These include economic, technical, social and environmental aspects.

Some of the issues still to be addressed including, size, permeability, composition, faults, and other technical questions, including whether fracking is the best method to extract the gas.

More information will be needed from state and company actors regarding many of these questions. Citizen participation will also be key to sort out and address the concerns that may arise from fracking proposals.

The Argentine Institute for Petroleum and Gas (IAPG), recently published a Best Practice Guidance for Non-Conventional Reserves, which covers stages including Planning and Preparation, Evaluation of Site, Design and Construction, Perforation, Stimulation, Backflow, and Production. [2]

ENVIRONMENTAL IMPACT ASSESSMENT AND PERMITTING REQUIREMENTS

In the United States, well permitting applications consider a number of factors, including "design, location, spacing, operation, and abandonment, as well as environmental activities and discharges, including water management and disposal, waste management and disposal, air emissions, underground injection, wildlife impacts, surface disturbance, and worker health and safety" (Ground Water Protection Council 2009: ES-2-ES-3).

DISCLOSURE

In order to address some of the public health concerns fracking poses, a TEDX report has made the following recommendations (Calborn 2011: 1054-55):

- "Product labels and/or MSDSs [material safety data sheets] must list the complete formulation of each product, including the precise name and CAS

[2] See: http://wp.cedha.net/wp-content/uploads/2013/01/IAPG-recs-sobre-gas-no-convencional.pdf

[Chemical Abstract Service] number and amount of every chemical, as well as the composition of the vehicle used to fill the product container”

- “If an ingredient does not have a CAS number it must be clearly defined, leaving no doubt about its possible health impact(s)”
- "Records should be kept for each drilling and fracking operation, listing the total volume of fluid injected, the amount of each product used, the depth at which the products were introduced, and the volume of fluid recovered”
- “The volume and concentration of all liquids and solids removed from the work sites should be made available to the public”
- “Air quality monitoring for individual VOCs as well as ozone must become standard procedure in any region where natural gas activity is taking place and must commence prior to initiation of operations to establish baseline levels”
- “Comprehensive water monitoring programs should be established in every gas play…both prior to and after gas production commences, that include new chemical species indicators based on toxicity and mobility in the environment, and pollution of sub-surface and above-surface domestic and agricultural water resources, and all domestically-used aquifers and underground sources of drinking water”
- “The development of labeled isotopic fingerprints of the chlorinated compounds in products used to drill and fracture…a plot of this isotopic data found down gradient of a hydraulically fractured well would aid a state or federal regulator in identifying the contamination source”
- “Public health authorities should establish an epidemiological monitoring….the design of the study should include environmental monitoring of air and water as well as any health changes in those living and working in regions of natural gas operations”
- “The exact location in the geological formation(s) in which [waste] is injected should become a part of permanent government records that will be publicly available for future generations”
- “Before a permit is issued to drill for natural gas, complete waste management plans should be reviewed and approved and become part of the permit”
- “The injection of hydraulic fracturing fluids should be regulated…to assure mechanical integrity of the injection wells and isolation of the injection zone from underground sources of drinking water.”

Alternative Technologies

A method introduced in 2008 offers a purportedly less onerous process for gas extraction. The method is called LPG fracking and uses propane instead of water. The LPG is 100% recoverable. A drawback of the LPG process is the high inflammability of propone. Thus far, little research is available on the process. (GasFrac 2012).

ECONOMIC BENEFITS

While hydraulic fracturing does present a number of environmental and health concerns, it is not without economic benefit. According to a report commissioned by the United States Department of Energy, “three factors have come together in recent years to make shale gas production economically viable: 1) advances in horizontal drilling, 2) advances in hydraulic fracturing, and, perhaps most importantly, 3) rapid increases in natural gas prices in the last several years as a result of significant supply and demand pressures.” (Ground Water Protection Council 2009: ES 1) According to the United States Energy Information Administration, with 774 trillion cubic feet (Tcf) of technically recoverable shale gas resources, Argentina is home to the world’s 3rd largest supply of natural gas, following China (1,275 Tcf) and the Unite States (862 Tcf) (United States Energy Information Administration 2011). Presuming natural gas prices remain competitive, natural gas extraction could bring an economic windfall. (Krauss 2011).

Argentina is in the midst of an energy shortage, and for the first time in seventeen years, the country’s energy trade balance showed negative in 2011 (Krauss 2011). Demand for energy grew five percent each year between 2002 and 2010 as Argentina recovered from its economic crisis from 2001-2002. However, insufficient investment in the energy field caused lags in production. Investment was further disincentivized by energy subsidies, which forced companies to sell natural gas at capped prices. While the global average was between four and five USD per million BTU, Argentine prices hovered around two USD. Neighboring Bolivia was even exporting natural gas at between ten and sixteen USD per BTU. Gas production companies were forced to compensate for supply shortages with imports – imports that have been growing exponentially since 2009 (Krauss 2011).

INTERNATIONAL INVESTMENT

Taking advantage of these large shale reserves will require considerable investment – around forty billion USD (Krauss 2011).

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