The Economical and Ecological Consequences of Hydraulic Fracturing in relation to America and Europe

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1 Acknowledgements and Declaration of Honor

I would like to take this opportunity to thank numerous people that I have met during my research at GVSU, as well as during my post-research activities in Austria.

In particular, I would the Marshall Plan Foundation for the tremendous opportunity to study at Grand Valley State University. I am also very grateful for the financial support of the Marshall Plan Foundation, which helped me to pursue my research at Grand Valley State University.

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I do solemnly declare that I have written the presented research thesis by myself without undue help from a second person and without using tools other than that specified. No part of this assignment is taken from other people's work without giving them credit. All formulations and concepts adopted literally or in their essential content from printed, unprinted or Internet sources have been cited according to the rules for academic work and identified by means of precise indication of source.

This report represents the ongoing problematic of non renewable energy sources and their extraction techniques. Especially, it focuses on shale gas production via hydraulic fracturing. This thesis was written on behalf of the Marshall Plan Foundation, who supported me during my semester abroad at Grand Valley State University.

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2 Introduction

2.1 Area of Expertise

The topic of this bachelor thesis relates to the production of oil and gas through hydraulic fracturing. The focus of this thesis lies on analyzing the ecological and economical consequences of this production method. Furthermore, circumstances that led to the so called “Fracking-Boom” will be looked at closely. Due the intensified use of fracking in the United States, a comparison to the European potential will be acquired. In order to study the economical aspect of fracking in today’s energy market, the immense influence of the Organization of Petroleum Exporting Countries (OPEC) must be taken in consideration. By producing the majority of oil worldwide, OPEC demonstrates its force by lowering the world’s crude oil price, resulting in a global struggle for power. Referring to the ecological aspects of fracking, health consequences for humans and animals, drilling related earthquakes, and water contamination will be addressed.

2.2 Introduktion and Problem Statement

Hydraulic Fracturing is the fracturing of a rock by injecting pressurized liquid. This process uses toxic water filled with sand, in order to create small fractures. After the hydraulic pressure is removed from the well, sand particles expand and maintain the fractures open. Throughout this procedure shale gas, tight gas, tight oil and coal seam gas can be extracted from the well.

With the energy demand constantly rising and a significant price increase of primary fuels over the last years, industries and companies, especially in USA and Canada promoted cheap ways produce energy. Shale gas and oil gained significant attention due to new technologies making these resources more accessible. Due to an oversupply of gas as well as oil emerging the energy market and rising pressure from Organization of Petroleum Exporting Countries (OPEC) a price decline had been the consequence Due to the run for cheap primary energy sources enabled by the fracking technology a temporary deflation of the gas price acquired. Unfortunately the ecological consequences of this hype have been particularly ignored by the Industry.

Since the United Stated of America devoted their attention to becoming energy independent, hydraulic fracturing has been on the raise. With the technology being executed continuously over the past years, fracking became the center of attention of a widespread controversy. Primarily due to the incidents that led to pollution of the environment, industry faces great resistance of an anti-fracking movement.

Proponents of the industry are pointing out that lowering the unemployment rate by creating jobs, offering a “bridge fuel” that can be the path to cleaner technologies, and reducing the energy dependence of other countries can be accomplished and guaranteed by prompting gas and oil production through hydraulic fracturing. In comparison to other fossil fuels tight gas has low emissions and is therefore seen as environmental friendly by the public majority.

Despite those positive effects extraction of tight gas through hydraulic fracturing has the reputation of being very risky and unsafe. Because of recent published studies and data, the position of Europe is seen to be very critical. Green Activists, tend to emphasize the negative aspects of gas and oil extraction, as contaminating ground water reservoirs and polluting air. The commonly used chemicals in the fluid are prone to have negative effects on the water quality if, by incident, fracking-fluids opt out of the bore hole’s casing. In addition to environmental damages, fracking is considered to being under suspicion of promoting health problems to its working personnel as well as triggering earthquakes. Recently, methane emissions produced by hydraulic fracturing operations, were addressed as one of the main emissions promoting global warming. With the Methane's ability of trapping considerably more heat from the atmosphere than Carbon Dioxide, Methane emissions recently fell into dispute.

Due to all contrasting opinions, a critical analysis of the effects on the environment and economy is needed to be published.

With the economical aspects of fracking mostly being highlighted, this thesis will focus on the ecological and economical aspects of fracking in relation to America and Europe.

In addition to the comparison to Europe and America, the influence of OPEC, especially Saudi Arabia, and Russia will be analyzed. Especially OPEC members like Saudi Arabia and Russia are major contributors to the global energy market and the ongoing energy crisis. OPECs current pressure on energy providers and energy producing countries will be analyzed in regards to the political and economical landscape.

Throughout the thesis essential question will be analyzed and regarded skeptical.

Does hydraulic fracturing have the right to exist in the 21st century?

Are the economical benefits in any relation to the ecological damage?

Does Austria have the resources and the capacity to implement hydraulic fracturing in today's gas production?

Could hydraulic fracturing be relevant with an enhanced security provisions?

2.3 Formulation of Question and Goals

The objective of the underlying thesis is the analysis of hydraulic fracturing in terms of ecological and economical parameter. Through comparing the past as well as the current situation in Europe and the United States, risks and the associated necessity of this energy source production method will be questioned.

The focus lies on the development of positive and negative aspects of gas and oil gathering as well as the operating mode through fracking.

The chemical composition of fluids being used, recommendations, and a risk assessment will not be supported by this thesis. However, the best-known chemicals will be addressed in regards of their use, as well as their usage in today's environment.

To get a significant answer to possible consequences of hydraulic fracturing the following topics must be addressed carefully

What ecological consequences have to be considered by the public if hydraulic fracturing is being implemented in the state's energy production?

What economical impact would a refusal or approval on the part of government have?

By which means did especially fracking gained such a tremendous boost in the United States?

What are the risks and concerns Europe has to expect if hydraulic fracturing is extensively introduced to their energy production methods?

Is it possible to minimize risks through new technologies?

2.4 Value and Relevance

The main reason for this thesis is raising the public awareness of the ecological and economical consequences of hydraulic fracturing. Another focus will be on presenting the state of the technology. On the basis of the achieved results and the analysis of data, such as the efficiency, costs and the ecological aspect this thesis will display the potential of hydraulic fracturing in Austria, Europe and America. To understand this work, no precognition of the reader in relation to gas production is required.

2.5 Methodology and Approach

To assure and maintain a high quality of this bachelor thesis, the access to the Grand Valley State University library has been an essential factor. The focus will be primarily on literature dealing with the environmental impact of hydraulic fracturing considering methods and technique. Therefore this bachelor thesis will concentrate on literature that is available in the GVSU Network. My research benefited from geology and environmental biology lectures that I chose to take during my semester abroad. As indicated above, having access to the GVSU Network and the library had a tremendous contribution to my work. By addressing students as well as professor with the problematic of hydraulic fracturing, I gained great insight into the mindset of hydraulic fracturing proponents as well as opponents. Those resources and even more the fact of being in the US, will make a tremendous impact on my research. A listing of sources I gained information and data from can be found in the bibliography, located at the end of the paper.

A public survey had not been relevant for this bachelor thesis, because of an overall lack of knowledge concerning consequences and risks of tight gas production.

3 What is Hydraulic Fracturing?

The extraction of natural gas from shale rock layers through vertical and horizontal drilling in addition to injecting highly pressurized fracking-fluid is called hydraulic fracturing. By creating new channels through pressure and fluids within the rock, natural gas is forced to escape in higher rates than usual (R. B. Jackson et al., 2013). It is vital to understand that hydraulic fracturing refers to a production method and not the shale gas itself.

The main problem arises through the geological conditions of shale. In fact, shale tends to be highly impermeable, reaching impermeability greater than concrete. As a matter of fact, due to the shale's impermeability it would take days for a methane molecule to move a few tens of a millimeter through shale formations. Further, centuries would pass to move a gas molecule about ten centimeters. With the ability to capture fluids as well as gas, it is mandatory to fracture shale, allowing the matter to flow. With that information kept in mind it is vital to understand that only a certain percentage of shale gas can be made available through fracking. It is the certain percentage of shale gas that already migrated into the natural fractures of the shale. This fact leads to only 7 percent of the total available Methane stored in a shale formation in the United States is extracted by natural gas productions. Furthermore, only 1 to 2 percent of the total available oil reserves are estimated to be recoverable. However, what has to be considered when talking about the production of oil is it's typically higher selling value (Ingraffea, 2014).

Against the common public belief of only one pad at a site, shale gas and oil production must be clustered, with multiple well pads at one site. Furthermore, it is often seen as spatial intense (Ingraffea, 2014).

As already mentioned, hydraulic fracturing cannot be seen as a drilling process; therefore the process is used after the drilled hole is completed. This process uses high pressurized liquid and "fracturing stimulates" in order to create small fractures in rocks which are considered to contain tight gas and fossil oil.

Therefore the rock will be injected with high pressurized liquid containing modified sand, which leads to several, up to 100 meter long cracks. To prevent the cracks from shutting immediately after, the used high pressurized sand serves as proppant. This method generates permanent and rugged fractures on behalf of enhanced fluency conditions for tight gas. To ensure that neither the fluid, that will eventually be pumped through the well, nor the oil or gas that will eventually be collected, enters the water supply, steel surface or intermediate casings are inserted into the well to depths of between 1,000 and 4,000 feet (300-1000 meters). The space which between the steel surface and the surface of the wellbore is filled with cement is referred as "annulus". This process repeatedly starts anew as soon as the setting of the cement reached its maximum and the wellbore reached about 6000 to 10.000 ft (approximately 3000 meters) (Habrich-Böcker, Kirchner, & Weißenberg, 2014).

Economically hydraulic fracturing has been on the rise since years. Therefore it was projected that the rapid expansion of hydraulic fracturing will make the U.S the world's largest oil producer by 2017. Moreover the United State's natural gas production could potentially increase to 49% by 2035 (Administration, 2012). After the global crash of the oil and gas price, these numbers are moved into distance.

With the targeting the ecological value of natural gas, it is often referred to as a fuel that wins over oil and coal in low emissions and a low environmental impact (Habrich-Böcker et al., 2014). However, during the last decade, this common belief started to fade, since studies indicated that Methane molecules have the ability to trap more heat from the atmosphere than Carbon Dioxide does. Throughout this thesis both theories will be analyzed and looked at closely.

Proven gas and fossil oil resources developed through compound thermogenic gas, which arises by degrading organic material located in slate under the ground. Influenced by high pressure and high temperature conditions organic material is converted into gas and oil. At a temperature of 65°C chemical reactions are starting to covert organic material into carbon compound. This process occurs at a depth of 2.100 to 5.500 meters, which is equivalent to 65 to 150°C. This temperature scale is provably responsible for the production of fossil oil. Thermogenic gas occurs at temperatures above 150°C.

With the conditions being beneficial for gas or oil development basins will ultimately form, containing the matter. The concentration of tight gas and fossil oil in comparison to solid organic material is low, despite having higher volume. Reaching the maximum, the bedrock is not capable anymore of holding and restraining, resulting in an oil and gas movement. As a result of the low concentration, oil and gas tend to penetrate water and other substances on their way to the ground. This movement through porous matter will come to stand, only by hindering underground material. Hindering underground material could be for example a caprock or a salt dome. The accumulation defined as an oil-and gas field or oil-and gas pool (Ingraffea, 2014). These oil and gas fields are then analyzed and explored by geological and seismic methods. By evaluation of the gained data, companies can plan their production.

4 Fundamentals of hydraulic fracturing in relation to drilling sites, deposits as well as the economical and ecological aspects

Since the start of this century, shale gas has become more important for worldwide energy productions. In the quest for energy security, natural gas production grew extensively over the last decades. Driven by the concern of not being able to cover the growing demand with conventional oil resources, the run for securing long-term oil supplies and alternative energy sources began. That were the beginnings of the extensive natural gas production (Jain, Sharma, & Agarwal, 2012). With shale gas only covering 1% of the U.S. domestic gas production in 2000, it only played a minor role for the production of energy. By 2010, shale gas productions rose up to 20% of the U.S natural gas production and was predicted to reach 46% by 2035 (Stevens, 2012).

Natural gas that is located in shale rock formations tend to have very low permeability and is related to as shale gas (Shale Gas Information Platform, 2012). In relation to the chemicals, shale has is a dry gas composed of methane. Shale is fine-grained sedimentary rock that is composed of mud with clay minerals and silt-sized particles, minerals, as well as quartz and calcite. When talking about hydraulic fracturing distinguishing between “conventional” and “unconventional” reservoirs is indispensable. While conventional reservoirs are characterized as being porous and permeable, unconventional reservoirs might include sandstones with a low permeability, as well as self-sourced reservoirs that are rich in organic matter. Shale gas shares this characteristic with “tight-gas” from sandstone and “coal bed methane” (CBM) (Montgomery, 2011). Depending on the permeability of limestone, the originating gas can also be labeled as “unconventional gas”. With the natural gas production via hydraulic fracturing, unconventional natural gas deposits are mostly targeted (Shale Gas Information Platform, 2012).

The permeability refers to the measurement of how readily fluids are able to interfuse materials. With a material being characterized by having a low permeability, matter, fluid, and gas are not easy to pass through the material, making production complex and costly (Montgomery, 2011). Because of the low matrix permeability of shale, gas production requires methods to create fractures and therefore provide permeability. A common method to provide fractures is hydraulic fracturing (Jain et al., 2012).

Looking at the area of North Dakota where the drilling of the Bakken takes place, 3 layers of casing are installed. The so called „Upside down wedding cake" is a casing-shape that refers to the different layers of casing that reduces its diameter by increasing depth of the bore hole. Until a depth of around 2000 feet, which is about 600 meters, it is required to drill with freshwater, until a certain shale-rock formation is reached. When drilling through and past an Aquifer a 13 ¾ inch hole is being drilled and cased with an 11 ½ inch casing, which creates a certain buffer of about an inch on every side. The space is referred to as "annulus", which gets filled with cement. After the installation of the first casing the casing shoe is placed at the bottom of the first casing. The casing shoe serves the purpose of determining the volume of the cement that is sent downwards. Additionally a plug will be installed on top of the casing shoe. The plug has a tapered hole in it that is designed to blow at a certain pressure and then fill the rest with cement. Then the top plug gets pumped down. When the bottom plug mates with the casing shoe and pressure is being added through pumping, the burst disk is forced to break. This forces the cement to go up and behind the casing. The space between the casing and the well bore is filled with freshwater- as you pump the cement down you should be getting water due to the displacing of the water. The water is therefore forced up because of the downwards pressure of the cement. This process is used to generate the casing of the well. The process of adding cement and pressure will come to an end as soon to the water that is referred to as “returns”, is displayed at the surface. To ensure that the cement casing is installed well, wire baskets that go around the casing are forced down the well. These wire baskets are referred to as centralizers. The springs keep the casing off the borehole, to make sure that the cement is being forced all around the casing.

After the surface drilling is completed a diesel invert, which is an oil or diesel based fracking fluid, often referred to as “diesel” or “oil based mud”, will come to use. Chemical additives generate the proper weight and viscosity for the job. The mud access has many purposes like clearing away the cuttings, accessing lubrication to the drill string, and is also used to power turbine power tools. After the isolation of the groundwater diesel invert will come to use. The second drilling hole is characterized by an 8 ¾ inch wide bore hole. When drilling with the invert, the drilling process is operated in the open-formation. Especially the rock formation known as the Bakken is rich of hydro carbons, which minimizes the impact of the diesel invert mud, since there oil and gas is already present. At this point, the area of operation has many confining layers above the casing the fluid has no chance to penetrate the layers until reaching the surface and groundwater. Further, the drilling process will be preceded from 2000ft (600 meters) to 10.000ft (3050 meters) until the kickoff point is reached. The kickoff point is determined by the area where the vertical drilling will not be proceeded anymore, but horizontal drilling is added to the process. Due to an about 90 percent curve the drill string will bend in order to drill horizontally. The second casing will be set inside the first layer of the casing which originates at the surface and ends in about 10.000 ft. When the second layer of casing is cemented a redundant layer of casing is being generated. The fluid that is used to drill the horizontal section, which is a 6 inch hole, is typically salt water or brine. To prevent the bore hole from collapsing a casing referred to as “liner” is introduced. When the frac-fluid is pumped out, the high pressure of the formation and the loss of stability would cause the bore-hole to collapse. The liner is not introduced to the frac-job to hold pressure, but to be later penetrated by a perforation gun. Due to an inverted copper cup and an explosive located behind the copper cup, the explosion of the hockey-puck shaped device channels the copper into a hot molten jet that punches holes and perforates the metal casing. The use of the so called “shape charge” generates holes and channels, through which oil and gas can be extracted. Additionally the use of the perforation gun will generate cracks throughout the formation, through which the actual fracking job will benefit from. The perforation job prepares the well to be fracked.

Propants water and chemicals that are used are applied in order to sustain the quality of the fracking operation. Further information about the used frac-fluids can be obtained in chapter “Chemicals use in hydraulic frac-fluids”. About 40 to 50 percent of the fluid that is used for the operation will reach the surface as flowback, which generates a tremendous problem when it comes to disposal.

If you take a look at the sedimentary column the layers exist of an “upper Bakken” which is about 30 ft thick, a 20 ft to 40 ft thick layer called “middle Bakken” which consists of dolomite sand- and siltstone, and is located below the “lower Bakken” shale. The actual drilling process will take place in the middle Bakken shale or “the three forks”, named due to the heritage and the source of the oil. Despite the advanced technologies, drilling in shale rock is up till now very difficult, since shale formations tend to be very weak rocks. Problems occur by stopping the pumping process when drilling through shale, which ultimately will lead the bore hole to collapse. This fact leads to the process taking place in the upper part of the middle

Bakken or the upper part of the three forks, which are located beneath the shale formations. Through drilling under the shale, producing cracks and fracking the shale, the instable formation will not be directly drilled through.

After the drilling process is completed, an artificial lift and a pump jet will be installed. Right after setting the casing, a pressure test will secure that the casing had been set properly. If the pressure that is forced into the casing stays stable, the quality of the casing can be secured. Wire-line logs are also often used to determine the quality of the casing. They are sent down the casing which records parameter like gamma radiation and resistivity. Through data analysis, cracks can be determined due to shifts and changes in parameters.

When it comes to the disposal of waste water deep injection wells are unfortunately still often used. They contain brine and are located very deep underground. Due to their incapability of being used as a freshwater source, the frac-fluid is pumped down in the deep injections well. Because of the quantity of the water that is pumped down the well, it can activate small faults, which can lead to earthquakes. These earthquakes are often related to as being produced by the extraction of oil and gas due to fracking. Another method of wastewater treatment is the reuse of the water. By reusing the fracking fluids, the amount of freshwater used for the process is minimized. Since water scarcity is concerning millions of people, all over the world, this technique is a positive contribution to saving water. The third option would involve cleaning up the water and dispose it to the nature. The disposal water will contain different chemicals that were not added to the water in the first place. Due to the containing chemicals in rocks that are drilled through, the water will be contaminated with different chemicals. Radioactive materials are also a concern that has to be paid attention to. Shale tends to be more radioactive than sand stone. Shale is made out of clay particles, those clays come primarily from felt spars. Felt spars are one of the common minerals. It is a silicate that contains silicon and oxygen. It is also a major component of potassium, which has many common radioactive isotopes. Potassium, Thorium and Uranium are the most abundant elements found in nature. Furthermore, Potassium tends to be very abundant. So when drilling through the shale, particles will contaminate the water and add chemicals to it. When cleaning the water hydrocarbons, chemicals, radioactivity has to be taken care of. This process teds to be very expensive and is therefore not often used by industries.

Since there are too little regulations, companies can often still choose their disposal technique, which often has a tremendous impact on the nature and environment. With more and stricter regulations the ecological impact of fracking can be minimized. Further information can be obtained in chapters “Water use and disposal of wastewater”, “Deep Injection Wells”, and “Impacts of shale gas wastewater disposal on water quality by the example of Western Pennsylvania” (Maddox, 2014).

Natural gas from shale is formed the same way as all hydrocarbons. Over time the remains of organisms were deposited in sediment on the bottom of the ocean. Natural gas is mostly formed in from decomposition of remains of plants, as well as organism. With the remaining organic matter of organism set under pressure by being buried, temperature increases steadily, triggering the so called “thermogenic methane generation”. Through accumulation of matter over millions of years, shale basins can form and accumulate large quantities of natural gas and oil. In most of oil and gas reservoirs the hydrocarbons migrate from the source rock until there is no further migration possible. Since the shale is fine grained and impermeable the accumulated gas cannot flow naturally. With the gas being trapped and stored in large basins underground, it is up to research and evaluations of geological formations to locate valuable gas and oil reservoirs. While the evaluations of the gas and oil deposits are fairly advanced, European studies are lagging behind (Montgomery, 2011).

In order to locate shale basins, as well as predicting shale formations in Europe over time and space, the first European interdisciplinary shale gas research initiative (GASH) was established in 2009. With focusing on the shale gas potential of Europe, especially on the Alum Shale in Denmark and the Posidonia-and Carbon Shale in Germany, an analysis of the US shale gas deposits is also conducted. Despite great effort on gathering information about shale reserves, information on shale gas reservoirs worldwide are lagging. As a matter of fact, since the majority of shale gas production is conducted in North America, ambitions to set up a worldwide research are minor. Summarized in the "Technically Recoverable Shale Oil and Shale Gas Resources: An Assessment of 137 Shale Formations in 41 Countries Outside the United States" report that had been published by the U.S. EIA in 2013, the majority of large gas formations of North America have already been exploited. It is also estimated that for some European countries shale gas resources might be larger than initially assumed. Especially Poland and France where evaluated as having great shale gas potential (Shale Gas Information Platform, 2012).

4.1 Unconventional process

In order to understand the potential of shale formations it is vital to have a look at the naturally occurring structure of shale. Shale that can produce natural gas is already naturally fractured. As a matter of fact, shale fractures were formed over millions of years and contain shale gas in between their gaps. In order to enable gas flow, the shale will be re-fractured through the human impact.

In the figure below (Figure1), the natural occurring geological structure of shale is shown.

Figure 1: Natural occurring fractures of black shale

Source: (Rygel, 2014)

Due to the lateral drilling of hydraulic fracturing, natural occurring fractures can be intersected and gas can be extracted. Despite drilling with a steel pipe that is characteristically impermeable, shale gas can penetrate the pipe sideways by reason of the perforation of the pipe. The perforation of the pipe creates holes and enables the gas to flow through the pipe. Despite the created excess points, gas that is stored in natural fractures will not flow easily. That is the reason why high pressure frac-fluid is forced downwards the production casing, by ultimately flowing into the natural fractures. This procedure fills up the fractures as well as opens them to a great extend. By capturing and storing the gas in the liquid it enables the transport through the pipe (Ingraffea, 2014).

After the perforating job, the frac-fluid has to be transported out of the well to enable the gas to appear at the surface. This fluid is called “flowback”. The so called flowback contains residuals of the actual chemicals that were added to it, prior to the job, but also contains chemical compounds of the actual shale formation. Salts, heavy metals, hydrocarbons, and naturally occurring radioactive materials are all prone to contaminate the water that has to be captured and stored at the surface. With an estimated volume of 8 million gallons of fluid per well, a great amount of hazardous liquid has to be taken care of (Ingraffea, 2013)

4.2 Infrastructure with spatially intense development and spacing development

4.2.1 Necessary infrastructure on fracking sites

In order to start with providing the necessary infrastructure for drilling operations a large area has to be first flattened. Through leveling the area heavy equipment that is mostly diesel powered can be established and positioned. It has to be considered that the actual drilling and frac-job only lasts for a couple of weeks. With that kept in mind, the majority of heavy machines on a site is removed shortly after the fracking process. After the fracking procedure is over, the heavy equipment will be removed from the site, only leaving waste water impoundments.

A Flow-back waste recycling pit contains all the contaminated flow-back fluids that have to be taken care of. Frighteningly some companies are known for their unusual methods to reduce the contaminated fluid. Through pumps that are located on the ground of the impoundment, contaminated water is distributed in the atmosphere. The goal is economical benefit through lowering the amount of fluids that have to be taken care of by evaporating volatile organics. Interestingly, regulations failed to restrict waste water impoundments to be located next to homes. Regulations only target the drilling process but not the necessary infrastructure.

The compressor station is facility that has to be located on-site, enabling the transport through pipelines by increasing its pressure. When the gas comes out of the well, it comes out at a couple 100 pounds per square inch pressure. In order to go to a transmission pipeline, the gas has to be compressed to a thousand pounds per square inch. Such a compressor engine has approximately 9,000 hp and runs for twenty-four hours, seven days a week, all year long. Furthermore, the operated compressor engine generates 110 dB, making noise pollution a crucial factor when living next to a site (Ingraffea, 2014).

Last of all, the natural gas liquids have to be taken care of. Processing Plants for natural gas liquids process it, refine it separate the oil from the natural gas liquids, and separate the natural gas liquids in propane butane methane (Landefeld & Hogan, 2012).

Due to certain regulations by the state or federal government drilling sites have to be chosen by strict criteria. Drilling locations are chosen by certain criteria like distance to buildings, access to roads, landowner agreements, and available water sites. The minimum distance form a rig to homes must be at least 300 meters. Initial drilling operations normally take about two month. When talked about a drilling pad, it is normally referred to an area on the surface where drilling occurs, that can be around 10 acres. However, multi-well pads are pads that host multiple wells. Due to a great number of wells on one single pad, frac-fluid is present at high amounts. Therefore human made ponds are constructed in the area of the pad, holding fresh water, returned frac-fluid “flow back”, and drilling mud.

Therefore, it is important to distinguish between the location of homes and the well pad, as well as the location of homes and other elements of the infrastructure, which might have health effects on humans (Landefeld & Hogan, 2012)

When talking about modern fracking sites, the term “spatially intense” is often used for description. Spatially intense development involves clustered pads that have multiple wells penetrating the underlying shale in different directions. In today’s energy production, shale gas production is only economically justifiable if it is spatially intense. As shown in the figure below, clustered pads with multiple wells that horizontally drill in multiple directions are applied. This certain picture shows the Fort Worth airport in Dallas of which drilling rights had been acquired by the Chesapeake Energy Corporation. It is noticeable that each red line is a different well and every red dot is an independent pad. With the complete coverage of the area, 18,076 acres provide space for 53 pads (Stevens, 2012).

Figure 2: Spatially intense development with clustered pads

Source: (Startelegram, 2010)

In order to operate a hydraulic fracturing job, an area of production has to be declared. This certain area is referred to as spacing or development unit (highlighted in yellow color). Typically the area has a rectangle like form with a pad in the center. Originating from the pad, multiple wells are constructed into different directions. It also shows that the leasing arrangement focuses on a wide area and not only a single spot. This reasonably creates spaces for the operating company to optimize the spacing of the laterals. These leasing arrangements of the spacing units usually have cover an area of multiple hundred acres. With the goal of producing as much shale gas as possible through the spatial intensity of multiple pads, the ecological impact is much more severe than the impact of conventional gas production would be (Ingraffea, 2013).

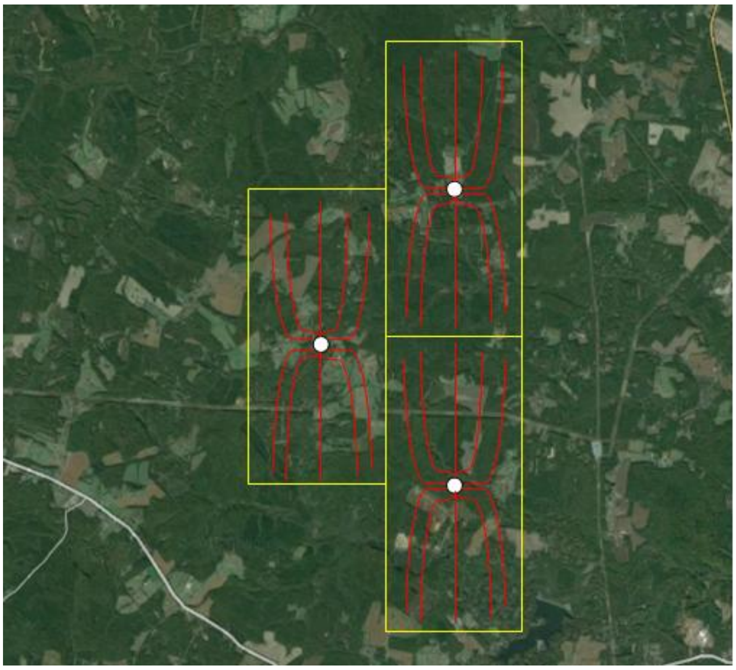

Figure 3: These leasing arrangements of the spacing units

Source: (Google Maps, 2015)

4.3 State of the art of seismic surveys

A seismic survey is a procedure where sound waves are reflected by underground geological layers. It is mostly used by petroleum geologists to outline reservoirs and estimate location and volume of reservoirs. This method is based on the principle of elastic waves being reflected by different layers of the earth. With different layers reflecting a different portion of the wave's energy back, a map can be modeled. The reflected waves are recorded over a certain time, also referred to as "record time". With data acquisition, processing and interpretation, it is commonly distinguished between three phases of seismic surveys. Starting with the "data acquisition" different techniques can be used for gathering of data. "Geophones" are detectors and receivers located on the surfaces that are portable, which convert the measured ground motion into an analog electrical signal. The seismic waves are often created by "Vibroseis" trucks that carry a plate, which vibrates on the ground, located under the center of the truck. When the vibration of the plate starts, the entire weight of the truck lays on the plate, generating more than 40,000 pounds of ground force. Estimated that multiple trucks are operating at the same time, hundred-thousands of pounds will be generated (Ringerwole, personal communication.2014)

This procedure lasts for a few seconds at every location and is depicted in the figure4.

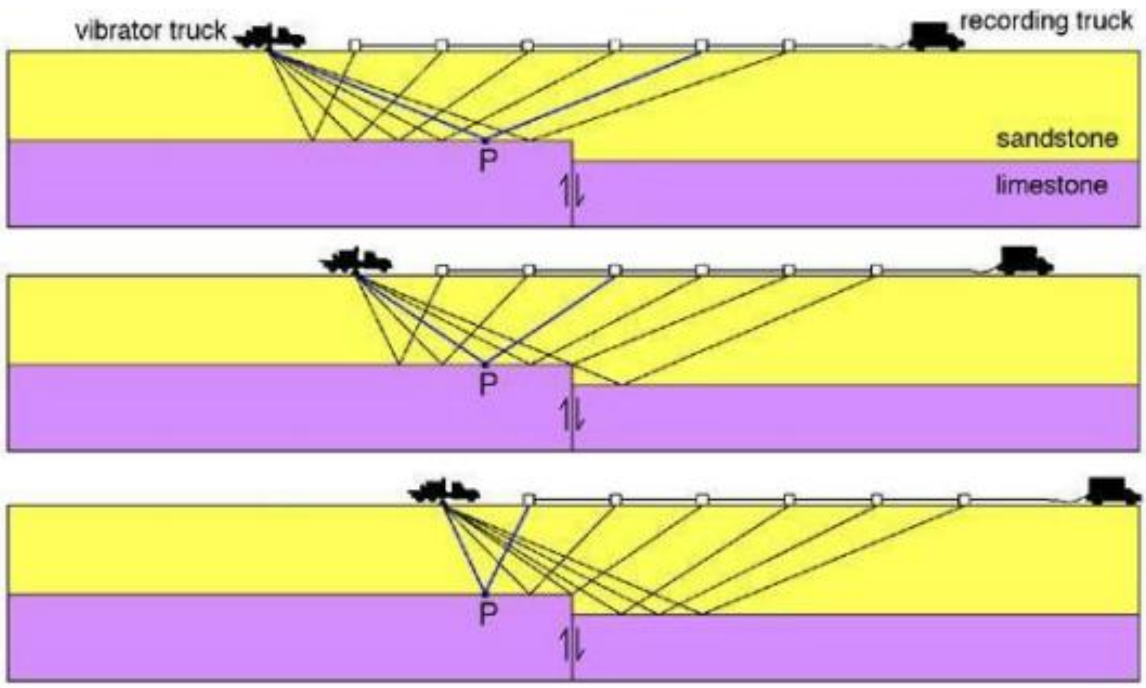

Figure 4: Seismic survey by "Veibroseis" trucks

Source: (McFarland, 2009)

When the gathering of seismic data is completed geophysicists can create a three-dimensional profile of the soil's composition. As displayed in the figure above, each receiver point is hit by different wave lengths, of different locations. With this data a three-dimensional image of the underlying surface can be created. With the data being unprocessed and unfiltered until this point, data must be filtered, stacked, migrated. These processes can take several months and can be very expensive. These sequences run under the name of "data processing". By analyzing many square miles of ground within a single evaluation of the potential, and a price of thousands of dollars per acre, seismic surveys are known to be very cost intensive.

Never the less, industries depend on these accurate evaluations of geological formations to plan future investments. In order to prevent mistakes and misinterpretations a couple of geophysicist and geologists evaluate the collected data and calculate the potential independently. This process is labeled as “data interpretation” (Ingraffea, 2013).

4.4 Stages in the production of Pipeline-Quality natural gas

In order to ensure pipeline-quality natural gas that can be fed into pipelines, different stages have to be consecutively completed. With the listing of the main stages of the natural gas preparation, the individual production sequences can be explained in depth.

4.4.1 Gas and Oil separators

Through pressure relief at the wellhead, which is precipitated from gravity, resulting in a separation of gas hydrocarbons from the heavier oil, a natural separation occurs. However, occasionally, a multi-stage gas-oil separation process must be introduced to the system to ensure the separation of oil and gas. Commonly separators have the shape of closed cylindrical shells, with inlets at one end and two diagonal located outlets at the other end. The outlet located on the bottom functions as valve for oil, whereas the gas can migrate through the top-located outlet. The separation of matter is supported by alternating cooling and heating intervals (Energy Information Administration, 2006).

4.4.2 Condensate Separator

With the alternating cooling and heating of matter, water and condensate might form. Often, condensate is mechanically removed from the gas steam at the wellhead. When the gas enters is fed into the processing plant, a inlet slug catcher separates the water ratio from the gas (Energy Information Administration, 2006).

4.4.3 Dehydration

The step of dehydration is vital for ensuring a trouble free process. It eliminates water that might otherwise be responsible for the formation of hydrates (Energy Information Administration, 2006). Hydrates form when gas molecules get trapped in water molecules at a certain temperature above 0°C and a pressure above one atmosphere. This correlation leads to the formation of a stable solid, which is related to as “hydrate”. To ensure hindering hydrates from their development, often ethylene glycol is used to absorb water from the steam. Ethylene glycol fulfills requirements such as being chemically neutral towards gas components and be low in viscosity. This process is also called glycol injection (Premium Engineering, 2015).

4.4.4 Contaminant Removal

The term “contaminant removal” includes the disposal of hydrogen sulfide, carbon dioxide, water vapor, helium, and oxygen. By adding an amine solution sulfur compounds can be absorbed from natural gas. After the desulphurization of the gas the remaining contaminations get filtered through a series of tubes. Smaller particles attach to each other and form into larger particles that, due to gravity, flow to lower sections of the section. As a result of flowing on other levels, particles can be filtered. Furthermore, the separation of water and small solid particles is achieved by centrifugal forces in a series of tubes (Premium Engineering, 2015).

4.4.5 Nitrogen Extraction

The use of molecular sieve beds is vital for a further dehydration. At this point the steam gets into a Rejection Unit (NRU) passing a multiple stages. By passing these stages, the nitrogen is separated and vented by one type of NRU unit. The other NRU unit separates methane and heavier hydrocarbons from nitrogen. By reducing pressure, the gained methane and hydrocarbons are separated from the solvent (Energy Information Administration, 2006).

4.4.6 Methane Separation

There are two methods that are applied when it comes to methane separation. The cryogenic method uses the cooling of the gas steam to about -120 degrees Fahrenheit, which is about -84 degrees Celsius. This temperature can be reached through the use of an external refrigerant. Due to the quick cooling of the gas condenses the hydrocarbons, while maintaining the methane in gaseous form. Thereby methane is separated. Due to absorbing oil being used at the absorption method, methane can be separated from the natural gas liquids (NGL). The oil is capable of absorbing large amounts of NGLs. With being heated in distillers above boiling point of the natural gas liquids, only the oil remains in a liquid condition. After being separated the NGLs will be cooled down and fed into a fractionator tower (Premium Engineering, 2015).

4.4.7 Fractionation

The fractionation is the last step of the stages in the production of pipeline-quality natural gas. Through varying boiling points of hydrocarbons, the remaining gas steam is filtered. When various liquids are separated they will exit through valves into storage facilities.

The gained product is referred to as “pipeline-quality gas” (Energy Information Administration, 2006).

4.5 Chemicals use in hydraulic frac-fluids

When talking about the hydraulic fracturing fluids it is vital to know that production companies are put great effort in keeping their chemical use as a secret. After all, gas and oil production is dependent on their chemical additives in order to prevent incidents and contaminations. But why are these chemicals rarely published, and what is the main purpose of these chemical enhanced fluids?

A short overview of commonly used additives, their purpose, and the common use in relation to its main compound, are listed below. It is important to bear in mind, that only a few chemicals were chosen to be focused on in this paper. Furthermore it is vital to understand, that approximately 99.2% of the frac-fluid consists of water (Fracfocus, 2015b).

Biocides: Its main compound is Glutaraldehyde (U.S Department of Energy, 2015)These are chemicals that eliminate organism that can have negative effects on health and materials. Due to their intrinsic properties the use is controversial (European Commission, 2015). Their use in hydraulic fracturing operations originates from bacteria located in the water that might cause corrosion (Fracfocus, 2015b). Biocides can be found in can be found in disinfectant, medical as well as dental equipment (U.S Department of Energy, 2015).

Breaker: Ammonium persulfate is one of the main compounds. When needed, the breakdown of gels can be delayed by the introduction of a breaker to the process. The breaker reacts with the gel and the crosslinker enabling a better flow to the borehole (Fracfocus, 2015b). Commonly it is used as bleaching agent in detergent and cosmetics (U.S Department of Energy, 2015).

Diluted Acid: With Hydrochloric acid or muriatic acid being one of the main compounds of this form of acid, minerals and cracks throughout the rock formation can be dissolved.

Diluted Acid finds its way in our households through being applied as a chemical for swimming pools (U.S Department of Energy, 2015).

Crosslinker: The result of having Borate salts as one of the main compounds leads to the ability of stabilizing the fluids viscosity in the case of a temperature rise. Crosslinker are used in soaps and cosmetics (U.S Department of Energy, 2015).

Iron Control: the great amount of Citric acid results in the ability of preventing precipitation of metal oxides. Resulting in simple salts, carbon dioxide and water, the iron control reacts with minerals in the formation (Fracfocus, 2015b). Commonly it is used for food additives as well as for enhancing the flavor of beverages (U.S Department of Energy, 2015).

Proppant: Consisting of silica and quartz sand, proppants are vital for the frac-job. Through keeping fractures open and staying there, hydrocarbons can be extracted through hydraulic fracturing processes (Fracfocus, 2015b). Interestingly the common use of the main compound is often used with the filtration of drinking water and plays a vital role in the production of concrete (Fracfocus, 2015b).

pH Adjusting Agent/Buffer: With having a large amount of sodium or potassium carbonate, the pH Adjusting Agent maintains the effectiveness of components that are important for the process of fracking. The maintenance of crosslinkers is only one benefit of introducing a pH Adjusting Agent. Commonly it is used for detergents, softeners, and ceramics (Fracfocus, 2015b).

Since water is used as a primary carrier fluid and horizontal shale gas wells can be fracked multiple times, the water consumption can take up to several million gallons of water. Due to the enormous quantities it is vital to have access to fresh water reserves at all time. Surface water of rivers and lakes are mostly taken as source for water supply. At first the quantity of water consumption might sound astoundingly high, but in comparison to the total water consumption in the United States in 2005, mining operations account for 1% of the total consumption (Fracfocus, 2015a).

4.6 Water use and disposal of wastewater

What the public majority fails to realize is the migration of waste water through solid rock formations from the depth of 1,700 meters, reaching 170 meters, which is seen as the ground water level, is very unlikely to happen. Advocates and drilling companies persistently argue that waste water incidents caused by drilling operations have never been recorded until this day. However, according to a study conducted by the New York City Department of Environmental Protection in 2009, concerns were raised by analyzing that wastewater originating from hydraulic fracturing could possibly migrate from the gas-bearing layers, located at 5,000 feet (1524 meters) below the surface upward to 500-1,000 feet (approximately 300 meters). By the example of the Marcellus shale gas drilling , where water contamination violations have occurred 346.6 times from January 2008 to August 2011, environmentalists and opponents of hydraulic fracturing addressed the government "(Taskinsoy, 2013).

4.6.1 Deep Injection Wells

Also referred to as disposal wells, deep injection wells are able to store any fluids like frack waste water. Since 1985 the Environmental Protection Agency (EPA) regulates permits and inspections through the Underground Injection Control Program (UIC) to ensure environmentally responsible behavior in the course of waste water injections. By the example of Pennsylvania, seven active deep injection oil and gas wells were in use in 2012. Fracking related waste water contaminated with high salt content, chemicals, radioactive material, and heavy metals are disposed in deep injection wells. Despite the availability of treatment facilities that filters the majority of pollution, a relatively small amount of fluid, or solid “cake” has to be injected into disposal wells. Besides the additional effort, the treatment of fracking waste water tends to be very expensive.

Three of the deep injection wells in Pennsylvania are labeled as commercial, allowing several companies to dispose their waste water in the same well. The remaining deep injection wells are only permitted to store their own frack water. Distinguishing in size and volume, wells might take up to 30,000 barrels a month (approximately 4 million liters).

In 2012, the EPA fined Exco Resources, who was forced to shut down two injection wells after discovering that the company deliberately injected waste water in spite of a leakage. Often, consequences of the injection of fracking related waste water are often neither known nor calculable. Besides the danger of contamination of water, the injection of waste water in deep injection well is also seen as responsible for earthquakes (NPR, 2012).

4.7 Impacts of shale gas wastewater disposal on water quality by the example of Western Pennsylvania

Since the beginning of oil and gas exploration, major challenges where associated with the disposal of the used fluids. They often contain high levels of salinity, toxic metals and gas and radioactivity. Especially in the U.S. different kinds of waste disposal techniques are being applied, with wastewater being treated and recycled for shale gas operations, injecting wastewater into deep disposal wells, feeding it in public owned and commercially used treatment works, as well as waste water treatment plants. Even through spreading on roads for dust suppression and deicing, the amount of waste is regulated. Especially the injection of wastewater is associated with polluting and contaminating the environment. The term "wastewater" of oil and gas exploration refers to drilling fluids, hydraulic fracturing flow back fluids and produced waters.

In 2011 it was estimated that approximately 70% of flow back fluids were reused. Despite the aim to excel the percentage in the following years, the treatment options of poor water quality fracking fluids tend to be very limited. In comparison to the reused flow back fluids, approximately 20 % of drilling fluids, 8% of hydraulic fracturing flowback fluid, and 14% of produced water from unconventional wells were reported to be discharged into local streams after being treated at centralized waste treatment facilities. The composition of the high salinity waste water typically consists of bromide, chloride, barium and strontium and naturally occurring radioactive radium isotopes. Due to hypersaline brines that occur in formations targeted for natural gas exploration, the flowback and produced waters tend to show a rise in salinity and radioactivity. As a matter of fact, the supply of wastewater from conventional and unconventional oil and gas wells to industrial brine treatment facilities has been practiced by the state of Pennsylvania since ages.

Toward to this process, the treated water is typically discharged into surface waters. Research revealed that the discharge of three facilities was suspected to increase the concentrations of Chlorine, Bromine, Strontium and Barium exceeding the maximum contaminant levels, criterion maximum concentrations, as well as the criterion chronic concentrations set by the U.S. Environmental Protection Agency (USEPA).

In addition, the wastewater of Marcellus is assumed to be the cause of an ascent of 5% in chloride concentrations at downstream surface water monitoring sites. Throughout the 2 year sampling period, a noticeable impact of the discharge on the surface water quality was observed. Downstream to the treatment facility, chlorine concentrations rose up to ten times to any other samples that were taken in western Pennsylvanian streams. In addition, data revealed that despite treatment of the discharge wastewater, isotopic rations in the effluent could still be traced back to oil and gas explorations.

By the example of the Josephine Brine Treatment Facility it has been shown that the there is a significant reduction of some chemicals when releasing it into surface waters. Despite this fact, the quality of the surface water was nonetheless reduced due to discharge of chemicals. The problem that occurred with the discharge of chemicals was the creation of a flux of chemicals to surface waters. This led to a creation of compound consisting of high levels of bromide and features in high concentration levels above the level of background. Especially the existence of radium in surface waters was shown to be very severe. With a half-life of 1600 years, radium will have a long-lasting contribution to environmental and health problems (Warner, Christine, Jackson, & Vengosh, 2013).

Concerning a New York Times investigation, waste water has inadequately been treated and dumped back into water supplies all over Pennsylvania. A single well can produce over a million gallons of waste water, contaminated with highly corrosive salts, radioactive elements due to the decay of rock formations, as well as carcinogens. In addition to the naturally occurring pollution, chemicals will be added to the fracking fluid to enhance its characteristics (Ian, 2011).

What the documents revealed had been far more concerning than expected. Wastewater has been deliberately hauled to sewage plants that did not meet the requirements for treating and discharging wastewater into rivers. Furthermore, the rivers of concern were exposed as water resources that supplied drinking water. In addition to several chemicals still situated in the water, the radioactivity levels were far higher than treatment plants could handle (Ian, 2011).

Despite these findings, the E.P.A did not take action. Furthermore, federal and state regulators agreed that radioactive testing will not be required by waste treatment plants when handling with hydraulic fracturing waste water. When thinking about the 71,000 active gas wells in 2006 and related amounts of wastewater channeled into the Monongahela River in Pennsylvania and ultimately into the Chesapeake Bay, consequences for more than six million people could be severe.

As a result of these findings E.P.A scientists published recommendations to sewage treatment plans to test frac-fluids for radioactive compounds. Furthermore, wastewater should not be accepted for treatment, if radium levels were twelve-times higher than the drinking water standard. Moreover, E.P.A scientists advise against discharging the treated water into freshwater resources.

Interestingly, the desire to put an ultimate ban on waste water discharge is only half-heartedly. Even inspectors of the Pennsylvanian Department of Environmental Protection are doubtful if stricter regulations are constructive in case of preventing further environmental pollutions. Generally speaking, oil and gas productions produce too much wastewater for supervisory bodies to ever keep up. As a matter of fact, the majority of incidents were reported by the oil and gas operators themselves. With stricter regulations and penalties, companies might stop reporting. This condition didn’t change during past years. Often, inspectors are simply dependent on the collaboration between industries and government (Ian, 2011).

4.8 Natural gas: A bridge fuel and a cleaner energy solution?

Throughout this chapter the focus lies on the value of natural gas as a bridge fuel. Further, Methane emissions distributed by natural gas will be compared to emissions of other energy sources.

Since President Obama referred to natural gas as an bridge fuel, that has the ability to lead to economical growth as well as reducing the carbon emissions, which are held responsible for the ongoing climate change. Moreover, with the aim of promoting natural gas, President Obama also addressed the Congress to reduce the amount of cars and trucks that are dependent on foreign oil to American natural gas powered vehicles.

Since 2009 the natural gas consumption, that is commonly used to generate electricity, has been continuously increasing. Due to this fact the question arises if natural gas can be seen as alternative energy source and therefore can be labeled as bridge fuel. In order to be labeled as bridge fuel, a fuel has to have the ability to power society with a minimum of environmental impact, while deploying renewable energy. Therefore, it is the goal to create time and space for renewable energy to grow and develop, while reducing the amount of greenhouse gas emitting fossil fuels. Despite not considering the factor of being able to reduce environmental pollution while lowering the national energy dependence, natural gas is often referred to as bridge fuel due to the reduction of greenhouse gases during its combustion process. To determine the economical and ecological value of natural gas in todays and future's society, energy transformation, the transfer from "cradle to grave'", and the extraction to end use, has to be assessed (National Geographic Education, 2014).

Natural gas is considered to be an odorless and colorless gas composed of 70-90% methane (CH_4) referred to as fossil fuel, which is a non renewable energy source. Further natural gas consists of ethane (C_2H_6), propane (C_3H_8), carbon dioxide (CO_2), hydrogen sulfide (H_2S), and nitrogen (N_2). Due to less impurities compared to coal and oil, natural gas emits less kilogram of pollution per unit of energy during the combustion process. Through millions of years, forces like intense pressure and heat forced layers of buried plants and ocean microorganism to form natural gas. The variation between the energy contents of different geological formations originates from different pressure and heat level exposures over time.

In fact, natural gas has a broad area of usage in the United States by being used by almost 50% of the homes for the generation of heating, cooking, hot water heaters, and clothes dryers. The industrial purpose of natural gas can be found in the generation of electricity for steel, paper, glass, and brick production. Natural gas often serves the purpose of generating electricity by the burning in boilers. Due to the generated power steam will occur and ultimately provide power for a steam turbine. Another technique often used by power companies is the combustion of natural gas in a combustion turbine. The use of natural gas in transportation techniques is still controversial. Still, natural gas being used more often throughout the United States to power fleets of buses. Los Angeles serves as an excellent example by the conversion of all Los Angeles Metro buses from diesel-powered buses to natural gas ones in 2011. To target the problem of the emission of greenhouse gases and improve the gas mileage more industries are considering natural gas fleets in terms of transportation. In 2014, United Parcel Service (UPS) announced that all new purchases of tractor trailers will use natural gas as fuel. Due to this upcoming trend, American and European automakers are making natural gas powered vehicles more affordable and available.

In order to evaluate the environmental impacts of natural gas compared to other energy sources, the carbon dioxide amount released will be addressed. This can be done by multiple methods, which will be analyzed. To start off, the mass of CO_2 emitted per amount of energy will be shown when combusted.

The following table provides evidence that the type of hydrocarbon as well as the combustion process itself reflects directly on the quantity of CO_2 emissions (National Geographic Education, 2014).

Rank	Fuel Type	Average kilogram of CO2 emitted per million British Thermal Units of Energy (Btu)
1	Coal (bituminous)	95.3
2	Diesel fuel and heating oil	73.2
3	Gasoline	71.3
4	Propane	63.1
5	Natural Gas	53.1

Chart 1: Average kilogram of CO_2 emitted per million (Btu)

Source: (National Geographic Education, 2014)

In addition to the table above information about the amount of energy released by different hydrocarbons has to play a role, when comparing natural gas to various energy sources.

Rank	Fuel Type	Energy Content in (kJ/g)
1	natural gas	51.6
2	Petroleum	43.6
3	Coal	39.3

Chart 2: Energy Content ranked by Fuel Types

Source: (National Geographic Education, 2014)

In order to analyze if natural gas can be seen as a bridge fuel, the “global warming potential” (GWP) over different periods of time has to be addressed. The following table will contain the global warming potential of carbon dioxide, methane, nitrous oxide, and sulfur hexafluoride over a period of 20,100, and 500 years. This information will provide evidence of the potential impacts on the natural environment. The impact of methane on climate change was evaluated by the Intergovernmental Panel on Climate Change (IPCC) as 20 times greater than CO_2 over a period of 100 years. Despite providing evidence of a methane being a very potent greenhouse gas, it is necessary to keep in mind that through production and manufacturing processes of renewable energy sources and technologies, greenhouse gases will also be emitted. With this fact often being left behind, the common belief of renewable energy sources having zero emissions is related to in public.

Greenhouse Gas	20-year GWP	100-year GWP	500-year GWP
CO2 Carbon Dioxide	1	1	1
CH4 Methane	72	25	7,6
N2O Nitrous Oxide	289	298	153
SF6 Solfur Hexafluoride	16,300	22,800	32,600

Chart 3: Greenhouse Gas Emissions

Source: (National Geographic Education, 2014)

The National Oceanic and Atmospheric Admission, the U.S. Environment Protection Agency, U.S. Department of Energy, and multiple Universities have all addressed the issue of methane leakage, or “fugitive methane”, when being extracted. Due to different research approaches and techniques, findings and results differ widely throughout the studies. By underestimating the amount of “fugitive” natural gas leakage by up to 50%, it is not surprising that results have been falsified. Currently there is great uncertainty about the actual amount of natural gas leakages during extraction and transportation. Due to the lack of data being provided and published, analyzing the “cradle to grave” processes of natural gas can be seen as very difficult.

When addressing the main question of natural gas being a bridge fuel, focus has to be laid on the definition of bridge fuels. When it comes to providing a cleaner option that primarily reduces our greenhouse emissions as renewable technologies gain in market share, natural gas has to be an option. It is proven that natural gas reduces greenhouse gas emissions, associated pollution, as well as being able to increase the national energy independency, more than current energy options. However it is not a long term solution. Natural gas will serve its purpose as generating time for renewable energy sources and technologies to develop. Sooner or later, natural gas will also be an environmental problem that has to be addressed (National Geographic Education, 2014).

4.9 Seismic risks

Induced seismicity is referred to fractions generated in deposits and caused by immediate intervention. This type of seismicity differs from natural earthquakes, in relation to its origin. The induced seismicity is consciously caused during the process of extraction, although those earthquakes are just slightly beyond their measurability. Experts believe that the procedure of hydraulic fracturing in preloaded formations can cause seismic activity of a Richter Scale 2, 3 earthquakes on the surface. Despite various earthquake incidents in Arkansas, Texas, Ohio and Colorado, damages on the surface could not be brought into any connection with fracking activities until this day. Interestingly, earthquakes around these areas have increased tenfold throughout the last 4 years. With the seismic activity increasing to this extend, scientists believe that induced seismicity be possibly the trigger.

Throughout the last several earthquakes have been well-documented that occurred simultaneously to fracking operations. Despite incidents were not clearly proven, there is a high probability of a coherence to hydraulic fracturing (StateImpact Texas, 2014). In spite of the possibility of only small magnitude earthquakes being triggered by fracking, the fact that human induced earthquakes exist must be alarming.

Proponents of hydraulic fracturing and the oil and gas industry have a different opinion and believe that there has never been an induced seismicity due to fracking operations (Karl, 2010)

According to the United States Geological Survey, an abrupt shift of a fault induced by the shaking of the ground can be referred to as earthquake. Low-magnitude seismicity can also be generated whenever rocks are fractured. The injection of fluids into hot rock, as is called for in some new and advanced geothermal techniques, can cause fracturing (Karl, 2010).

The underlying study evaluated seismic activities at the Barnett Shale of Texas between November, 2009 and September, 2011. The program was carried out under the National Science Foundation and consisted of several hundred continuously recording of three-component broadband seismometers on a 70-km grid. The area of research covered a 400-km broad area from the Canadian border to the Gulf of Mexico. 25 of these stations were located near the Barnet Shale. The focus of this study laid on providing data for the relationship between the occurring of earthquakes and the nearby injection of wells.

The vast majority of wells located in Texas are being used for the disposal of waste originated from petroleum production, as well as for the stimulation of oil and gas production and are therefore classified as Class Two wells. Underlying the control of the Texas Railroad Commission (RRC), companies are constrained to report all information concerning the disposal of fluid waste and the use for stimulation of production.(Frohlich, 2012)

Over the two year study 1,330 seismic events where reported by the positioned stations. Based on wave-compressional wave intervals, 24 percent of the reported earthquakes were left unvalued due to its occurrence outside the study area.

507 events were identified as quarry blasts due to the characteristically much larger surface waves and weaker P and S arrivals. When talking about quarry blasts it os refer to the controlled use of explosives in a quarry. Because of different S and P waves characteristics, these events were able be identified and excluded. P or known as primary waves propagate within the body of rock. Therefore they are often referred to as body waves. This type of wave is capable of traveling through different kinds of media, including fluids, water and air (EPA, 2014). S-waves or secondary waves on the other hand propagate only in solid material, like rock. It shears the solid matter sideways (EPA, 2014).

P waves are commonly felt first at the emerge of an earthquake. Seconds later, the S waves are held responsible for the actual shaking and movement of the ground.(Rogers, D, 2013)

The recorded and evaluated data showed that these events commonly never occurred at night and on weekends, with epicenters being located within 1, 5 km from a visible quarry. Furthermore, the investigation showed that a majority of epicenters were located within a close range of injection wells. Small scale earthquakes with a magnitude of 2 or smaller were located only within a few kilometers of injection wells. This fact might provide information about the origin of small scale earthquakes but again, it has to be mentioned that there had been no proof of induced earthquakes by hydraulic fracturing operations (EPA, 2014). However, induced earthquakes are often connected with wastewater injection in disposal wells, which had already been mentioned previously in chapter “Deep Injection Wells”.

4.10 Impacts of gas drilling on human and animal health

Since gas and oil exploration is on the rise, health and environmental problems seemed to occur more frequently, with creating a myriad of potential risks of contamination. It is believed that wildlife and organism could serve as an indicator of potential health risk, due to a significant shorter life span. Substances that are used for a frac-job are often not published by industries and operators. Additionally to toxins that are being used, heavy metals, volatile organics and radioactive compounds are set free due to the decay of soil and the exploration itself. With the use of approximately 5.5 million gallons of water for a single well, for one frac-job, it is reported that up to 70% of the used chemical fluid remains trapped under the ground. Objecting a 25-40 year lifespan of a well that is capable of being fracked multiple times, a tremendous amount of fluid will remain captured in the ground (Bamberger & Oswald, 2012)

Due to high density gas emissions the risk to human health is tremendously greater among population located within a distance of 0.8 km of a fracking well (Meng & Ashby, 2014). A potential danger also occurs with methane concentrations found in drinking water wells within 1km of a frac-job, as explosions may be triggered. Despite a low probability of this scenario to occur, it is still vital for the development of a risk assessment on hydraulic fracturing (Osborn, Vengosh, Warner, & Jackson, 2011).

Since gas and oil productions consist of several processes it is important to distinguish between the actual frac-job and actions that have to be taken prior to hydraulic fracturing. A study of 48 water wells analyzing the chemical composition in regards to the dissolved methane content of pre- and post-drilling well-water showed no statistical difference. In spite of the distinct results, the analysis had been carried out on wells that have not been fracked but only drilled. Interestingly enough 28% of the water supply owners reported changes to their water supply after drilling jobs were executed within a distance of 3,000 feet of a gas well. (Boyer, Swistock, Clark, Madden, & Rizzo, 2011). Since well owners might feel personally motivated to manipulate drilling operations close to their homes, information of residents have to be taken with caution.

Most commonly, it was reported that problems with the reproduction of cattle declined. These animals were reported to being in contact with contaminated waste water, which implies flowback and produced water of fracking sites. Breading cows exposed to these fluids, incidents of stillborn calves were often reported, which had often been a consequence of liver and kidney malfunctions and failures. In this study, a total of seven farms were observed, showing 50% of the herd birthing stillborn or having disabilities. In one case, 17 cows were found dead within an hour because of direct exposure to frac-fluid. The main cause of those deaths was later reported as a respiratory failure with circulatory collapse.

During the study cases of reproductive problems and neurological problems, like seizures and ataxia were most commonly reported by owners. In fact, the majority of owners used well or spring water for their cattle and themselves. Burning of the eyes, respiratory symptoms, headaches, dermatological, vascular and gastrointestinal were commonly reported by the owners itself. Documented cases of six states implicated a connection between exposure to contaminated fluids and serious health problems of humans and animals. Tracing these impacts on health is often very difficult, since companies do not need to publish their used chemicals.

Documented complex studies targeting the consequences of exposure to frac-fluids on animals, livestock, organism and nature have to be expanded in order to prevent greater long-lasting damage to the environment and health. These long-term studies can be used as an essential tool to new governmental protection plans and restrictions. (Bamberger & Oswald, 2012)

A study that has been published in January 2014 focused on the impacts on birth outcomes and maternal residential proximity to natural gas development in rural Colorado. The main objective was to examine possible connections to neonatal mortality and the natural gas development between 1996 and 2009 in rural Colorado (Lewis, 2014). During this time period, 124,842 births and their outcome were examined (McKenzie et al., 2014). According to the study, remaining in an area of fracking operations may contribute to a rise of risks for infants developing birth defects by 30 percent. (Lewis, 2014)

Taking in consideration that approximately 15 million people live in distance of only one mile of a fracking well, data provided by these studies have to be taken seriously. With an amount greater than 125 wells per mile, infants were twice as likely to develop neural tube defects as infants that were located in an area without the influence of a well within a 10- mile radius. The research process was performed on 59 cases.

Throughout the study associations between the amount and area of exposition of natural gas wells in distance of 10 miles and the development of coronary artery diseases were found (McKenzie et al., 2014). According to different studies that researched the maternal exposures to organic solvents, results also revealed associations to major birth defects (Brender, Suarez, Hendricks, Baetz, & Larsen, 2002).

The conclusion of the study, targeting the birth outcomes and maternal residential proximity to natural gas development in rural Colorado, suggests an association to natural gas exposure within a radius of 10 miles of a well, as well as possible developments of coronary artery diseases. Despite those researched results no association to oral clefts, preterm birth, or reduced fetal growth was found.

Recent studies executed by the Colorado Old and Gas Conservation Commission expect that approximately 12.220 (26%) oil and gas wells in Colorado are situated in an 150 to 1000 feet radius from a living environment (Colorado Oil and Gas Conservation Commission, 2012). According to Lisa McKenzie, a research associate of the Colorado School of Public Health, 50,000 active oil and gas wells are currently located in Colorado, with another 50,000 wells estimated to being added in the next 15 to 20 years. (Lewis, 2014) These numbers gain in importance since a study suggests that endocrine-disrupting chemicals, which are found in frac-fluids, have the ability to restrain and affect the body's hormonal functions. No less than 700 chemicals are being used in hydraulic fracturing fluids, which could trigger metabolic, neurological and reproductive diseases (Lewis, 2013)

Since these data reveille an impact on infant's, analysis of current and future impacts of the oil and gas production and their emissions relating to the human health have to be extended and enhanced.

4.11 Human Impact on Climate Change

It is a common belief that methane emissions as a result of shale gas production has little effect on the environment and therefore is a proper alternative to carbon dioxide emissions. Moreover methane is often labeled as “bridge fuel” for renewable energy due to being a clean fossil fuel. To address the problematic of emissions, recent studies evaluated the impact of methane emissions from a climate change perspective.

As with every oxidation, fossil fuels emit carbon dioxide when burned. Carbon dioxide is commonly known as primary concern in terms of climate change. Emissions originating from industries, traffic and energy production are ranked as the main sources of pollution. As already addressed in the chapter “Natural gas: A bridge fuel and a cleaner energy solution" Coal productions are ranked among the greatest carbon dioxide emitters. Carbon dioxide increases currently at a rate of 2ppm per year. In the year 2011 it had already reached 391.80ppm. With an estimated “tipping point” (point of no return) of approximately 450ppm, it would be reached in about 30 years.

By producing shale gas through hydraulic fracturing, methane is also emitted in the atmosphere. In comparison to carbon dioxide, methane is a much more potent greenhouse gas. In fact, over 20 years, methane tends to be 105 times more potent than carbon dioxide. By having the ability of one methane molecule trapping more heat than a single carbon dioxide molecule, a rise of methane can have severe consequences (Ingraffea, 2014).

With all that information about the dangers of methane emissions the question raises which processes cause methane pollution.

After the frac-job, methane enriched fluid appears at the surface as a “flowback”. On one hand it can be flared, which again leads to light, noise and heat pollution and on the other hand it might be vented. Through venting methane is released into the atmosphere without any treatment. Interestingly, because of lack of regulations it is still possible for industries to release high amounts of methane into the air.

In order to understand the extent of methane emissions related to gas and oil production, you have to take a look at the whole infrastructure. Methane is reportedly emitted during the drilling process, the unloading of liquid, the processing of gas, as well as the transmission, storage, and distribution. All these factors have to be included into potential methane leakages.

Another problem that is highly underrated is leakages from old pipelines. Unfortunately until reverently there had been very little knowledge of the total methane leakage. As a matter of fact, concerns about these kinds of leakages had been minor.

As a result of these findings, multiple studies have been conducted with the approach of analyzing methane emissions at basins. Published in the international weekly journal of science “Nature” in 2013, data had been gathered showing leakages at up to 9% of the total gas production at the Uinta Basins in Utah (Bond, 2013).

The following studies went even further with examining distribution pipelines in Boston, New York, Washington D.C with focusing on possible methane leakages.

In the case of Washington D.C, around 5,893 pipeline leaks were reported within an area of 1,500 road miles. In order to prevent any mistakes at evaluating methane concentrations emitted by gas leaks and not humans, only methane emissions above 1.9 ppm (parts per million) were recorded. This is the amount of methane humans tend to emit through breathing. What had been recorded were multiple gas leakages distributed all around the city. Areas of leakage included the capital building, distribution pipelines, transmission compressor stations as well as the storage units (R. B. R. Jackson et al., 2014).

To display methane emissions data had been digitalized and evaluated. With the picture below methane emissions of aging urban distribution pipelines around the city of Boston were depicted (Phillips et al., 2013).

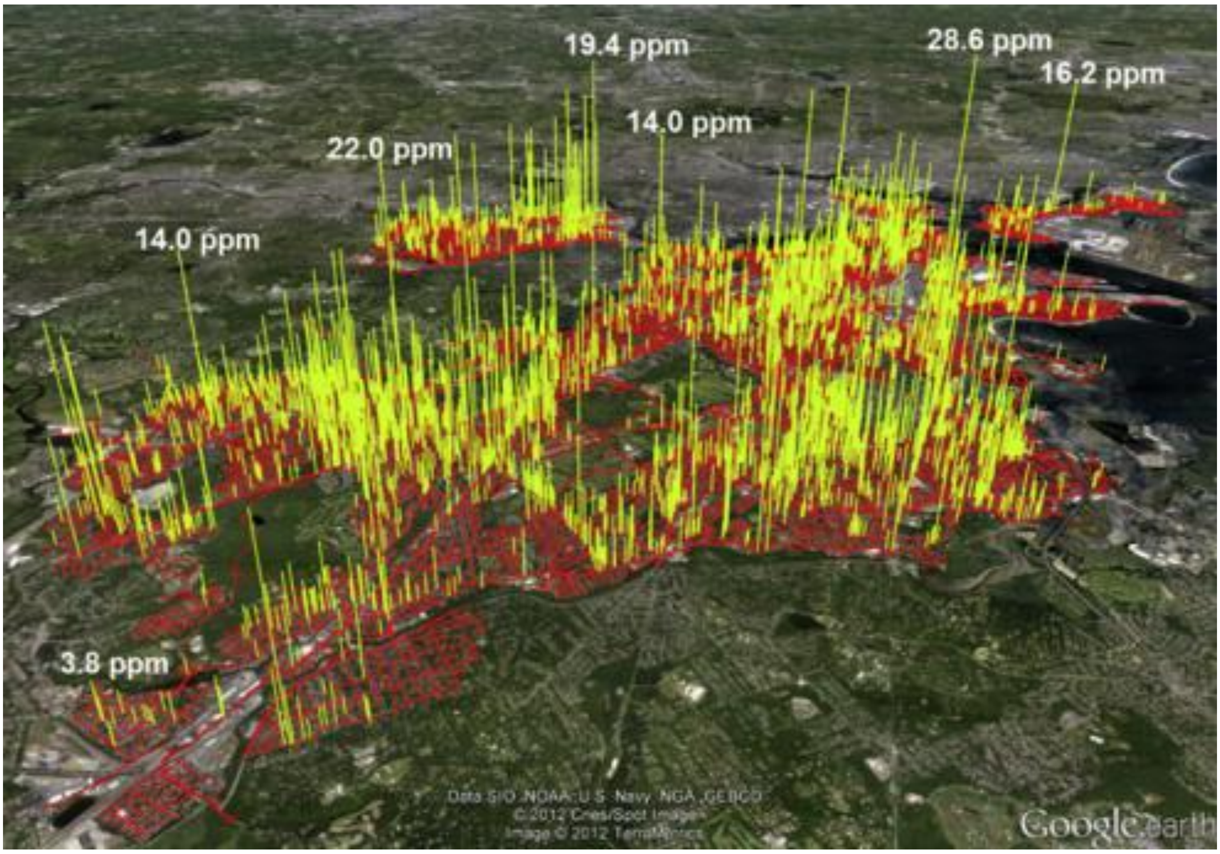

Figure 5: Methane leakage from aging urban distribution pipelines in Boston
Source**:** (Phillips et al., 2013)

At Cornell University, a study had been conducted, targeting this problem. With comparing shale gas, conventional gas and coal in terms of their methane-, indirect carbon dioxide- , and direct carbon dioxide amount, Howarth and Ingraffea published a paper at "Nature" in 2011. Against the public believe, both concluded that shale gas might be the dirtiest fossil fuel. Resulting in the great emissions of methane, all benefits of shale gas would become void. Howarth and Ingraffea conclude in their paper, that only a substantial reduction of green house gases like carbon dioxide, methane and black carbon can effectively preserve the climate from changing and ultimately reduce the rise of temperature (Ingraffea, 2013). These findings originated from a study published the international weekly journal of science "Nature" in 2012. The data that had been interpreted by Ingraffea can be found in the figure below.

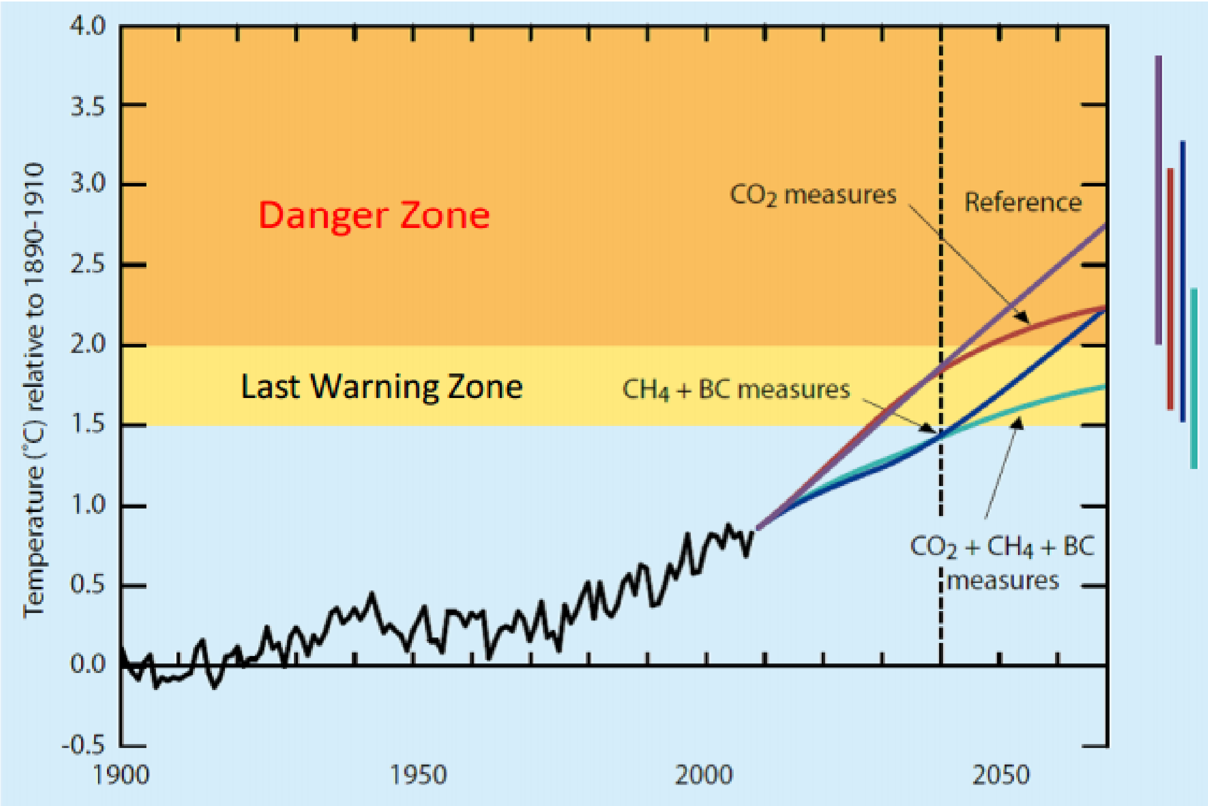

Figure 6: Forecast for Methane emission on global warming

Source: (Shindell et al., 2012)

This chart shows a trend prediction of global warming depending on types of emissions. The data stating from 1900 to 2010 had been measured, while data until the year 2050 had been estimated. Originating from the year 2012, four independent scenarios were calculated. The first scenario deals with disregarding any warnings and keep on burning the same amount of fossil fuels, which results in hitting the danger zone in 2042. The second scenario, indicated by a red line, deals with carbon dioxide reduction being the only measure that had been taken. The effect would be very little, only prolonging hitting the danger zone a couple years later. Thirdly, the reduction of carbon and methane, with maintaining the carbon dioxide level, the warning and the danger zone would be reached about 20 years later. Still the problem would stay the same. This scenario is indicated by the blue line. The only scenario that might have had the consequences of not reaching the danger zone would have been the reduction of the usage of all fossil fuels. By now achievements in reducing the use of fossil fuels failed, making the scenario of reaching the danger zone in the future more likely (Shindell et al., 2012).

4.12 The hydraulic fracturing of the Marcellus Shale

The Marcellus Shale is a designated as being Devonian-aged shale, which was named after typical rock exposures, occurred in Devon, England. Due to its high concentration of organic matter and the resulting black color, it is often referred to as dark shale that was deposited around 390 million years ago. Being a part of the Hamilton Group that is located in New York, the Marcellus Shale is known to be one of the oldest of these groups of rocks. The geological formation distinguished itself of being located deeper beneath the southern tier, with being exposed at the surface near the north end of the Finger Lakes region. This area includes a town called "Marcellus", which served as an indicator for the shale's name.

The area of expansion reaches from parts of New York to Ohio, West Virginia, and Pennsylvania. Shales located at the Marcellus were known to be low points on continents, which were affected by flooding by marine water. Geological similarities to gas-bearing shales can be found in multiple geological attributes. Fine sedimentary particles and organic matter, concentrated amounts of brine water, naturally occurring radioactive materials combined with a low permeability are only a few characteristics that characterize these shales (Smrecak & Team, 2011). The measurement of how readily fluids are able to interfuse materials is referred to as permeability. Influential factors of the permeability of a rock are related to the extent and size of interconnected pores and cracks. Bigger the pores tend to have a lower surface-to-volume ratio and a less frictional drag.(Montgomery, 2011)

The reason for the extraordinary amount of fossil fuels located at the Marcellus Shale can be found on the northeastern shore of the sea, close to Albany, NY. Plate tectonic activity created mountains with high topographic profiles to the east, which altered in intense erosion by carrying sediment into the Marcellus sea basins. Due to the presence of algae and platonic organism in the sea, that died and deposited on the ground of the basin and resulting low oxygen level on the ground, organic matter did not decompose on the floor of the basin. Despite being a part of the Hamilton Group, the Marcellus Shale is untypically poor of fossil, but wins over its commercial natural gas potential due to its former undecomposed organic material, that became natural gas.

In order to express the organic richness in these shales, the (TOC) Total Organic Carbon was introduced. This indicator for organic richness depends on the existing balance between the planktonic input, the amount of decomposition allowed to take place, and the sediment input during deposition of the shale gas. The Oatka Creek shale, which is referred to as “Union Springs” shale, is a zone that is located between the western and the eastern part of the basin and where the preserved organic matter is the greatest. This can be traced to the high sediment input on the eastern part and the waters high oxygen level in the west. As mentioned before, the Marcellus Shale is seen as a subdivision of rock formations in the Hamilton Group that in turn forms just a part in the Devonian. Throughout the last 55 million years several units of the Devonian generated natural gas and oil reservoirs, with the majority of areas underlying Pennsylvania (Smrecak & Team, 2011).

Shale is also known as a detrital sedimentary rock, which is characterized by their composition of weathered and eroded particles which formed by the compaction of rounded sitlt-and clay-sized grains. Additionally, silt, clay, chemical materials and organic matter are also present in shale. Formed in deep ocean water, lagoons and lakes, it is estimated that the sedimentary rock located on earth's crust composes approximately out of 50% shale rock, which is composed out of clay particles that tend to be less than 0.004 mm in size (Department of Natural Resources South Carolina Geological Survey, 2005). The chromatic appearance of shale may vary due to variations of minerals present in shale. Due to very high content of oily kerogen, which on account of its organic matter appears in black color, it appears to be very valuable for oil and gas exploitation. Despite being unfeasible when extracted, natural gas and liquid oil can be removed when heated in an oxygen-depleted environment.

Despite advanced technological techniques, there are still some areas of the Marcellus Shale that cannot be fracked economically. Reasons can be mostly found in very low permeability below 10^{-9} miliDarcies (mD) (Smrecak & Team, 2011).

4.13 Resistance against fracking in Denton, Texas

On November 4th, a referendum on a fracking ban took place in Denton, TX, passing the ban with 59 percent of the vote.

Adam Briggle, a professor of philosophy at the University of Texas, serves as the president of the "Frack Free Denton" initiative. Due to the tremendous natural gas production in Texas, approximately 33% of the country's extracted fossil fuel can be traced back to Texan origins. Especially Denton is affected by the oil and gas production, since it is located atop of the Barnett Shale, which is recognized as being one of the biggest natural gas reserves in the country. Despite the success at prohibiting new wells within 1,200 feet (360 meter) of a living environment in 2013, it is reported that already existing wells tend to be much closer. With increasing amount of data of health and environmental problems being published, the concern of contamination through fracking emissions rose in public. Especially the fear of water and air pollution located close to communities and schools were key trigger for this ongoing movement (Hennessy-Fiske, 2014).

To give utterance to the problematic exposure of gas and oil extractions to the public, the following representatives were reported to the media. Industries expanded their property as far as drilling wells on church property, school grounds and right next to the tennis court of the University of North Texas. These intrusions in public living space are due to the lack of owning mineral rights of property owners. This bizarre condition can lead to a property owner not being able to restrict well drillings on his own property (Goldenberg, 2014).The state and energy providers challenge the ordinance with separate lawsuits in two district courts, arguing with the loss of value of the mineral interest owner's property (Hennessy-Fiske, 2014).

Banning fracking in Denton will ultimately result in a wave of lawsuits from companies as well as mineral rights owners. With more than 15 million Americans estimated to live within a radius of one mile from oil or gas well, this movement could have a tremendous impact.

5 Economical aspects of hydraulic fracturing in relation to politics and geographical conditions

5.1 European fracking potential

The gas extraction potential of unconventional sources causes great disagreement between experts. Besides Poland and Great Britain, Germany, Belgium, France, and the Netherlands developed great resistance throughout the past several years. This movement not only focuses on fracking but on coal gas as well. The negative attitude against fracking goes so far as the Robobank, Netherlands biggest bank, not lending money to companies that promote unconventional gas as well as farmers and land owners that support unconventional gas extraction by providing their property to companies.

This attitude and resistance cannot be generalized since the European Union didn't put a ban on fracking at all but rather leaving the choice to their members. With different politics and dependency on foreign gas producers, the controversial subject of fracking is treated differently. Throughout the following sections, the potential of gas production is analyzed in highlighting the situation in France, Poland, Great Britain, and Austria in terms of dependency of Russian gas.

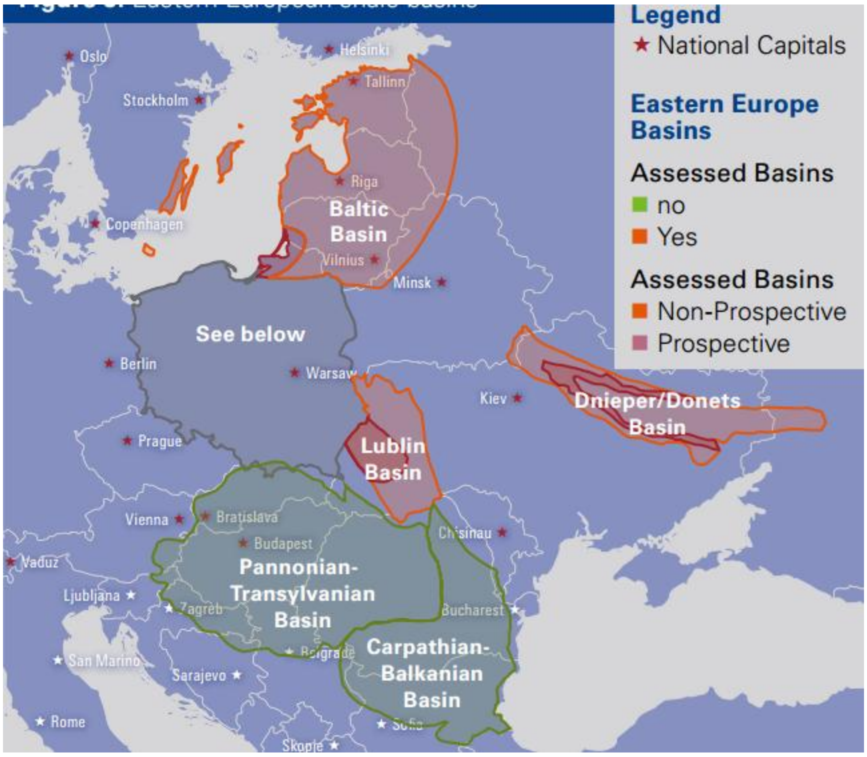

Figure 7: Eastern European shale basins

Source: (KPMG International, 2012)

5.2 Will fracking make Europe less dependent on Russian gas?

In the first paragraph the focus will lie on the situation in Great Britain.

Because of the crisis between Russia and the Ukraine, advocates of the fracking technology raise their voice and claim hydraulic fracturing extractions to be established in the UK. It is estimated that around 40 percent of Russia's natural gas imports are shipped through Ukraine's territory (Brittlebank, 2014).

Despite Great Britain not dependent on Russia's huge natural gas reserves, Russian gas makes still a small percentage of imported energy. Needless to say, that this would not only have an impact on the energy independency but rather on politics.

“Fracking will be good for our country", David Cameron said as he blamed a "lack of understanding" about the process for some of the opposition to shale gas.

The prime minister even said that one hydraulic fracturing is implemented into the energy production portfolio of Great Britain, more public enthusiasm would develop. As a matter of fact, exploiting shale gas reserves could help Europe to drastically reduce the reliance on exports from Russia (Press Association, 2014).

David Cameron insisted that it is the duty of the UK to find alternative energy sources in order to reduce the leverage of Russia internationally. Concerning Cameron, UK is not reliant to natural gas reserves from Russia to any extend. Therefore the main benefit lies on other European countries, which are almost 100% reliant on Russia's gas.

The potential of natural gas extraction in Europe, especially in the UK, in south-east Europe, and potentially in Poland and the Baltic states is very high, according to David Cameron. Opponents of Hydraulic Fracturing would be convinced of this technique, once functioning gas wells will run in the UK.

David Cameron is planning to run a few unconventional gas wells that will soon change people's minds.

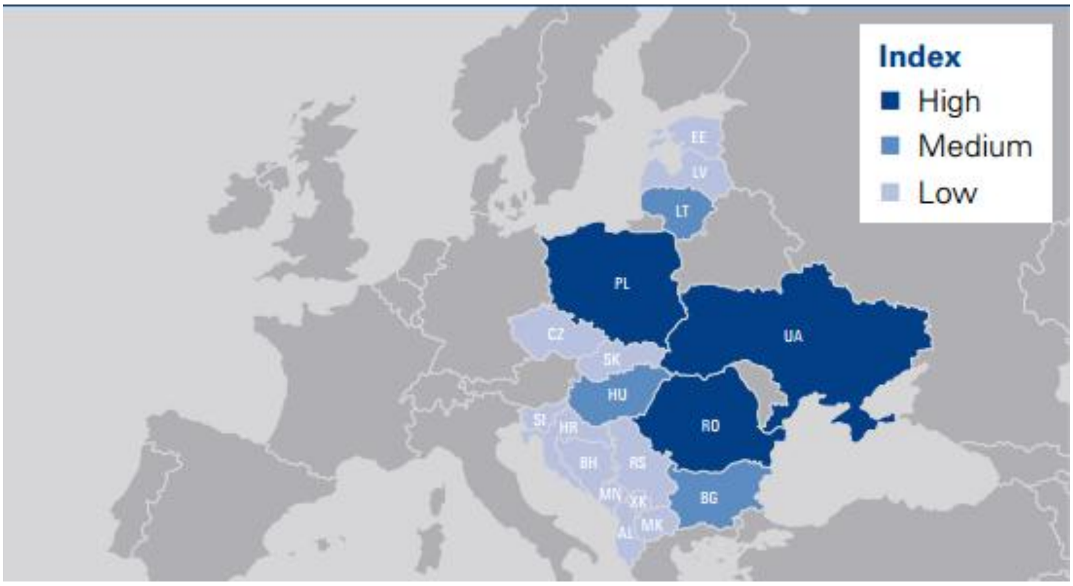

Figure 8: Shale gas potential index in CEE

Source:(KPMG International, 2012)

5.3 The fracking movement in France and Poland

With banning fracking explorations and production, the anti-fracking movement had strong impact on politics in France. Despite banning hydraulic fracturing successfully in France, the movement had minor impact in Poland.

5.3.1 Hydraulic Fracturing in France

France and Poland have the greatest potential for natural gas exploration throughout Europe.

Frances deposits were estimated to approximately 5 trillion cubic meters large. Located in two major basins only a quarter is seen to be extractable.

Around the city of Paris, the Paris Basin, and the Southeast Basin covering Provence and Rhone-Alpes, is the location of the major basins, which interestingly have geological similarities to the Bakken Basins in Texas (Adams, Stocker, & Lawson, 2011). In 2010, 64 permits were divided between foreign energy providers and national oil and gas companies (Weile, 2014).Those wells serve as a blessing and a burden at the same time.

The majority of natural gas in France is imported, making the country partly dependent on providers. In fact, 98% of the natural gas that covers 14% of France's energy consumption is imported (McGowan, 2012). To reduce the vulnerability of fluctuation of gas prices and supply, France draws gas from several different countries, including Russia, Algeria, Norway, and Netherlands. Even though great concerns about nuclear reactors, 74% of France's energy originated from nuclear power (Schneider, Froggatt, & Thomas, 2011). As the government promoted shale gases positive aspects France's shale gas industry expanded quickly (Weile, 2014).

With Sarkozy awarding several permits to the shale gas industry Grassroot campaigns close to the area of explorations became politicized by building the first Green Party. Due to the rising resistance of the opposition the government issued a moratorium on fracking which resulted in a complete ban on fracking in June 2011 (The Guardian, 2013). Even though licensed companies including Schuepbach Energy and Total SA held several permits, they were deprived from their right of exploration (Bloomberg, 2013).

As Francois Hollande took office in 2012, he stated keeping the fracking ban in place (Martor, 2014). Concerning a statement of President François Hollande, Hydraulic fracturing explorations will not be allowed despite the countries ambition of reducing nuclear energy and lowering cost for the consumers at the same time (Bloomberg, 2013). The responsibility concerning environment and Industry is not to underestimate due to the pioneering role of France. Advocates of fracking sense the possibility to be independent of natural gas imports motivated by the example of the U.S. According to IEA it is estimated that the U.S's oil output surpasses Saudi Arabias by 2020, making the Country almost self reliant (Nguyen, 2012)

5.3.2 France's Movement against fracking

France's anti-fracking movement can be labeled as a grassroot movement, with support from different economically and politically influential allies. Approximately 74% of the population declare themselves as preferable to renewable energy sources. In contrast, only about 9% favor shale gas explorations. Even more crucial to the resistance is that 89% of French consider themselves as concerned about nearby fracking projects that take place in their area (Eurobarometer, 2013).

Initially, water scarce areas that were dependent on water for agricultural purposes formed a major part of the movement against fracking. The high amount of water used for extracting gas and oil in the process of hydraulic fracturing and the possibility of groundwater contamination were mainly addressed by the public and opponents.

In order to obtain more popularity regarding to hydraulic fracturing operations, companies presented mostly economically beneficial key figures. With highlighting the creation of jobs and economical wealth, industries tried to downplay dangers. Mostly due to the lack of information, the public's knowledge and opinion based on research data and documentary coming from the United States. Several protests and gatherings concerning the dangers of hydraulic fracturing were the consequence (Asop, 2012).

With the growing public resistance and great political controversy hydraulic fracturing was banned in 2012 (Bloomberg, 2013)

5.3.3 Hydraulic Fracturing in Poland

Despite similar oil and gas reserves Poland is undergoing a fracking revolution, other than France.

In order to reduce the energy dependency on gas and coal imports, Poland was looking for new ways to produce energy. According to the United States Energy Information Administration around 5.3 trillion cubic meters of shale is located underneath three large formations covering the area of Poland, securing energy independence for as much as 900 years (Johnson & Boersma, 2013). Needless to mention that euphoria spread around industry and public, already looking into an energy independent future. Despite the euphoria dropping with the Polish Geological Institute analyzing that only about one trillion cubic meters consists of recoverable shale gas, it still looked promising for international gas companies as geological similarities to formations in the United States were found. (Tallents, 2008)

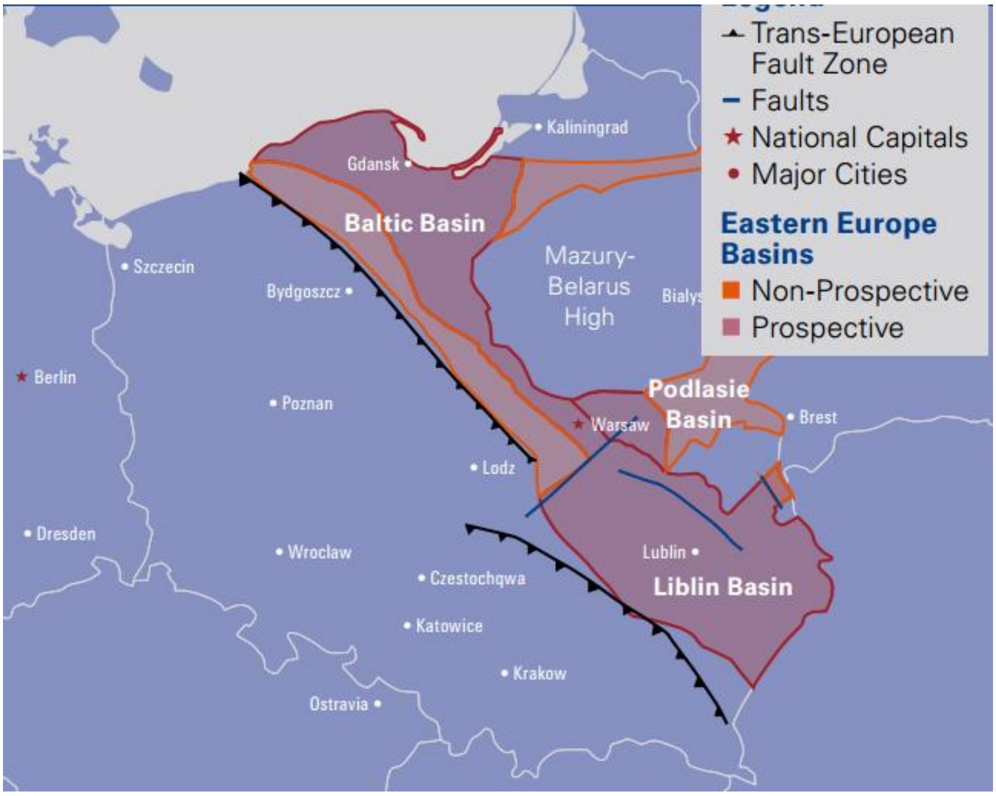

Figure 9: Polish shale basins

Source:(KPMG International, 2012)

The importance of gaining more energy independence results in the fact that 63% of Poland's natural gas consumption in 2010 was imported .Despite natural gas only covering 13% of Poland's energy supply, 90% of imported natural gas comes from Russia, making Poland vulnerable (Kádár, 2014).

Furthermore with having the highest share of coal consumption among EU countries in 2010, coal covers 55% of Poland's energy consumption. Because of the current EU guidelines regarding the reduction of CO2 emissions, pressure increases for finding alternatives (Barteczko, 2013). With the Polish government strongly emphasizing the importance of implementing hydraulic fracturing as it creates jobs and economical wealth, more than 100 concessions were awarded to multiple gas companies (Kenarov, 2013).

Infrastructural problems, smaller reserves, and poorly developed technology in Poland resulted explorations being on halt in 2012 (Naumann & Philippi, 2014).

With 2013 the National Operator for Energy Resources was constituted serving control functions by regulating the distribution and controlling concessions. New laws favored the state by taxation increases, resulting foreign companies to retreat from the promising market (Niemuth & Westphal, 2014).

5.3.4 Poland's Movement against fracking

According to a Eurobarometer survey in 2013, 32 % of polish inhabitants could see shale gas as energy option. In comparison to 9% of the population of EU members who are rather cautious about shale gas production. This behavior mirrors Poland's attitude towards concerns regarding fracking in neighborhoods. The majority of people tend to be not concerned about hydraulic fracturing near neighborhoods (Kádár, 2014).

Environmental organizations, politicians, and local farmers formed a network that composes out of different groups, addressing various fracking related problems. Due to the strong interest of Polish's public in economical benefits such as increased pensions, environmental organizations were undermined (Wood, 2012). Moreover the industry's influence on politics and government allowed companies to expropriate landowners if they refused to provide and sell their property (Materka, 2011).

Local activists successfully prevented Chevron from drilling in Zurawlow as only permits for seismic test were issued by the government. Despite examples like Zurawlow, success in counteracting remains rare. Due to the lack of success and political power, the anti-fracking movement remains marginal (Kádár, 2014)

5.4 Fracking in Austria

In May 2011 statements were released that the drilling of pilot holes at the “Wiener Becken” area are planned to be conducted. The extraction of shale gas had been the main objective of OMV’s efforts. In cooperation with the University of Leoben, OMV developed a Fracking method different to the U.S model, naming it “Clean Fracking”, safe for the environment and nonhazardous for humans according to Gerhard Thonhauser, Drillingexpert at the University of Leoben. (Krüger, 2012)

According to Sven Pusswald, spokesman of OMV, studies show that great potential lies in an area close to Poysdorf, which is located about 70 kilometer from Vienna. The estimated shale gas wells throughout the Poysdorf area are situated in 4000 to 6000 meter depth.(APA/MN, 2011)

5.4.1 “Clean Fracking”

With OMV’s effort to promote “Clean Fracking” originates from three major improvements in comparison to the controversial technique.

1. Water soluble admixtures are used in comparison to petroleum based fluids
2. Aborticidal of alga and bacteria influenced by UV light, instead of biocides
3. Closed circuit and recycling of Fracking reservoirs and reservoir water

Despite often promoted, it has never been conducted.

Interestingly an American company called Halliburton already promoted similar inventions in 2009. The main changes concerning to hydraulic fracturing extractions are listed below and explained in detail.

1. **CleanStim™ Formulation**
2. **CleanStream™ Service**
3. **CleanWave™ Water Treatment System**

5.4.1.1 *CleanStim™ Formulation*

The new fracturing fluid provides more security for the environment and humans, by including ingredients from the food industry. Despite of ingredients by the food industry it is not being considered to be eatable. The fluid system components include a gelling agent, crosslinker/buffer, breakers and a surfactant. The operator then has to mix the CleanStim™ Formulation with water. An advantage of this new fracking fluid is the ability of being applicable to gelled fracs and water fracs, commonly used in shale reservoirs.

Through the new technology following challenges as well as problems concerning the regular fracking process can be addressed and solved (Halliburton, 2012b)

5.4.1.2 *Water consumption and bacteria growth*

The water consumption and bacteria growth is primarily a problem in areas of water scarcity and drought. Due to bacteria growth in fracturing fluid that can cause equipment damage, chemical biocides are required. Halliburton's CleanWave water treatment system requires less fresh water through recycling processes of flowback and produced water at the well site. To address the problem of bacteria growth in fracking water, Halliburton uses ultraviolet (UV) light to reduce the growth of bacteria, what ultimately minimizes the use of biocides (Halliburton, 2012c).

5.4.1.3 *Fluid system with higher margin of safety*

Through ongoing research operators want to improve performance and efficiency of fluids to ensure the fluids ability of handling a variety of viscosities without failing.

Halliburton therefore uses its CleanStim formulation. This hydraulic fracturing fluid is entirely made with ingredients from food industry to ensure environmental friendliness. With excellent performance in terms of pumpability, proppant transport and conductivity Halliburton supports environmental friendliness (Halliburton, 2012c).

5.4.1.4 Reduce chemicals transported to well site

The development of fracturing fluids at the well site presumes the use of liquid gel concentrates that are transported in a hydrocarbon carrier fluid. Therefore hydration can be controlled. For that reason water-based fluids contain small amount of hydrocarbons.

Halliburton developed a blender to deliver the agent. The transportation of chemicals will be drastically reduced by using a dry powder that is mixed right at the well site. This treatment will reduce spilling due to transportation accidents to a minimum (Halliburton, 2012c).

5.4.1.5 CleanStim™ Service:

Bacteria can cause great damage to transportation and hydrocarbon production. Effecting fluid, piping and the formation itself, this high potential threat has to be taken seriously. Due to a biofilm, which is produced by aerobic bacteria, plugging and fouling of tanks and piping are the consequence. In order to prevent plugging UV light comes into use, causing damage to the DNA of the bacteria, enabling a stoppage to the reproduction.

This system is applicable to gelled fracs and water fracs and can therefore be used for conventional gelled fracs. This fracking technique need a substantial amount of proppant (Halliburton, 2012b).

5.4.1.6 CleanWave™ Water Treatment System:

To guaranty the water treatment an ADP™ advanced polymer blender comes into use. Fracking fluids which are no longer useful to the extraction get blended with liquid gel concentrates. In addition fracing fluids systems can be mixed out of dry powder.(Halliburton, 2012)

Figure 10: ADP(TM) Advanced Dry Polymer Blender for Fracturing Fluids

Source: (Halliburton, 2012a)

5.4.2 Current fracking situation in Austria

In 2012, OMV AG put their plans of drilling for shale gas in Lower Austria's wine country on hold. According to a statement released by OMV AG that they are awaiting final analysis of comprehensive environmental and social studies by the Federal Environmental Agency and TÜV Austria. Due to the expected shale reserves located in the area of Lower Austria expectations sound promising forecasting coverage of 30 years for domestic requirements. In spite of the company's afford to persuade the public about the save and responsible handling of fracking, the resistance of environmental and local citizen groups did not stop. Even the Governor of Lower Austria, Erwin Pröll, addressed concerns about possible impacts of hydraulic fracturing with the aim to precluding the drilling for shale gas (Natural Gas Europe, 2012).

5.5 Economical impact of the hydraulic fracturing boom

By highlighting that hydraulic fracturing created 1.7 national million jobs and is expected to create another 1.8 million jobs in the next 20 years, industries promote and justify excessive fracking productions. This number might be misleading to some extent, since the majority of the jobs were created by industries that are in close contact to fracking operations. Manufacturing companies and small communities tend to generate the greatest number of created jobs, while the actual number of fracking-related jobs might not increase drastically. With approximately 3 weeks of employment at one location, the fracking industry keeps employees in part year contracts, making it a temporary activity as an employee.

Even more concerning is the fact that up to 51% of the jobs of which are created by the fracking industry are ascribable to the “drilling and well construction phase”, which only lasts for an average of 50 to 100 days. Additionally it is estimated that up to 98% of the work force of on-site jobs originate from the drilling phase. The remaining 2 percent are ascribable to the “production phase”, summing up to 5 percent of total jobs. Furthermore it is vital to know that every 100 wells create 17 full-time jobs but 41,000 part-year jobs (Waxman, 2015).

With the development phase of hydraulic fracturing, the creation of infrastructure is the main objective. The creation of roads, the preparation of the chosen area and the building of facilities that can support the hydraulic fracturing production tend to be very labor intensive. Due to economical benefits the required workforce leans towards low-skilled employees that come from local communities. Despite of the majority of workforce requiring heavy physical activity, scientists, engineers, inspectors, geologists, and other experts are also required. These specialists are mostly out of town workers, who are bound to a certain project for a long period.

With that said, the majority of long term contracts are held by out of town workforce that does not have a long lasting positive contribution to the local community. Because of the local rise in labor, the dependency on housing also increases. With an incline on demand, the price will also adjust. This scenario ultimately leads to problems for residents with small income, families, as well as elder people. Moreover, industries and departments like firehouses, police departments, ambulances, hospitals and schools will notice a reduction of employees and volunteer. With an increasing population due to hydraulic fracturing productions, the burden to fulfill the demand increases drastically. In order to counteract exploitive industries in local communities a "severance tax" had been introduced (Waxman, 2015).

This tax is charged to producers associated with the extraction of a non-renewable resource and is in addition to federal and state income taxes (Investopedia, n.d.) The severance tax is meant to help local communities to insure the costs associated with the production. This involves the maintenance and construction of roads as well as environmental protection. In general, taxes originating from the extraction of non-renewable resources are deposited in fund (Pless, 2012). Severe problems arise when communities don't have sufficient funding to meet the demands of an extractive industry, which can lead to an inability to maintain roadways or the entire infrastructure in the future (Waxman, 2015).

Despite all negative aspects, industries and locals also gain from the extraction of non-renewable sources. With hydraulic fracturing being introduced to the energy production techniques, potential economic benefits developed. Natural resources extraction industries have a tremendous impact on the local economical wealth.

When drilling companies move to a location new jobs will be created in retail and service. With landowners being able to sell their property and the drilling rights, economical wealth will be generated for individuals. Despite providing jobs and labor for the region's population, the economic boom often results in a "boom-bust" that severely harms the regions tourism and agriculture. As analyzed by Pennsylvania's Marcellus Shale Education and Training Center (MSETC), the majority of jobs will be required for the Drilling Phase and will reduce to minimum at the actual Production Phase. To underline the problematic the "Boom-bust cycle" as well as the example of the "Boomtown Williston" will be analyzed (Waxman, 2015).

5.6 Boom-bust cycle

The rapid increase in economic activity, followed by a rapid decrease due to the extraction of non-renewable natural resources is referred to as "boom-bust" cycle. On account of the rising generated demand for non-renewable resources such as natural gas, companies and businesses settle in areas of productions in order to extract. Needless to say, that with growing economical wealth in this area, the local population starts to grow, retail and sales increase, and jobs will be created. With the boomtown infrastructure on the rise, road maintenance, schools, as well as public transportation arise. With the renewable resources being depleted an economic bust is the consequence. As population and jobs depart the region, the support for infrastructure will be reduced to a minimum.

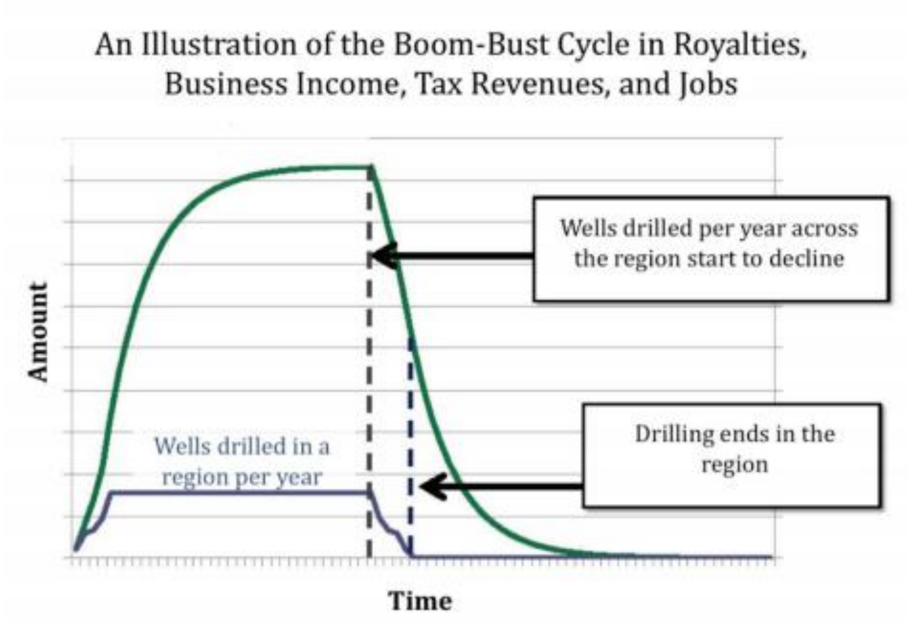

Figure 11: The Boom-Bust Cycle in Royalties, Business Income, Tax Revenues, and Jobs

Source: (Christopherson, 2011)

Through analyzing the geological and technological possibilities, a forecast of the total potential natural gas reserves and the capacity of existing or/and anticipated technologies, called shale gas plays, can determine the duration of the boom period cycle. Furthermore business dynamics of energy firms, providing costs and delivery rates of well operations, can be crucial for identifying the trend of the cycle.

For the example, high initial production rates dropped off rapidly in the Barnett shale plays predicting a sooner “boom-bust” cycle in the Marcellus Shale area. In spite of the significance of these figures, caution should be exercised with overvaluing this information. Especially the Marcellus Shale shows complex geological formations that might be wrong valued. In order to mitigate the effects the speed of extraction has to be adjusted to long-term economic development. Only effective planning and a responsible handling with the resources might reduce the “boom-bust” cycle (Christopherson, 2011).

Because of intense industrial activity agriculture and tourism suffer from great loss. In order to analyze the impact of industrial activity in tourist intensive regions, the economy of Southern Tier will be looked at closely.

Famous for its agriculture, breathtaking landscapes, and viticulture the region of South Tier attracts tourist from all over the world. In 2008, the tourism and travel sector accounted for 3,335 direct jobs contributing to $66 million in labor income. Moreover, visitors spend $239 million due to tourism. To local as well as in state taxes, the tourism sector accounts for a total of almost $31 million in tax revenue. In spite of the tourisms annual economical value, there is no doubt that oil and gas extractions might surpass in state revenues. What must not be neglected is the fact that whereas the majority of tourism related businesses are locally owned, gas and oil industries operate globally transferring revenue to out of state locations, causing the “boom” effect. In regards to the “brand” and reputation of the region, the ability to attract tourists might be influenced by impacts of drilling including visual impacts, compressor stations, traffic, noise, pollution, potential degeneration of waterways, and pricing as well as availability of hotels (Rumbach, 2011).

According to a study by Pennsylvania’s Marcellus Shale Education and Training Center (MSETC) about 98% of jobs are significantly involved in developing the gas well consisting of performing fracturing processes, casing the well, drilling, and developing infrastructure. This indicates that only 2% of jobs are required for the long-term “Production Phase”. With only one worker needed to operate 6 wells under production, the production phase is less labor intense (Jacquet, 2011)

These findings can be summarized as a duty of policy and governance to the realization of the economic long term development potential. With exploiting reserves long lasting economic damage might be caused to resource dependent communities.

5.7 Boomtown Williston

Named after geological a formation typical for the area of North Dakota, the “Bakken-County” is well known to be valuable for oil production. In 2014, 1 million barrel of oil was produced per day, equivalent to 140 million liter in North Dakota. With North Dakota being the “Boom-Land”, the formerly small town Williston got labeled as “Boom-Town”. With approximately 12.000 inhabitants Williston used to be rather small back in 2004. After the economic potential was discovered, the number of inhabitants rose up to 35.000 in 2014. Due to the oil production jobs were created and unemployment dropped to 0.6%. In comparison to the year 2004 where 3.213 pumping stations produced 79.000 barrel of oil, 10.105 pumping stations accounted for the daily output of 934.000 barrel in North Dakota. Because of the rising demand of oil, companies settled and build the infrastructure necessary to ensure a high quality of production. This development had great impact on the population, as roads, transportation and hotels were introduced to the city. Several locals were fortunate enough to sell their properties and drilling rights to companies which resulted in great wealth (Stumberger, 2014).

Shortly after industries settled, prices for rent multiplied and supermarket chains branched, offering twice the conventional salary (Hermann, 2015). In contrast to several other states political and social disputes barely exist. Despite unpublished chemicals used in the frac-fluid North Dakota’s government agreed to label the fracking method as secure in 2011 (Stumberger, 2014).

Due to falling oil prices the prevailing situation is not promising anymore. To produce oil profitably at the Bakken-Shale, prices must not undercut 60 dollar per barrel. According to Jim Arthaud, founder of MBI Energy Services who is specialized on the transportation of fluids as well as sand as part of the fracking process, 20.000

jobs will be cut during the next 6 month. Michael Feroli, chief economist of J.P. Morgan Chase, even predicts that if the oil price does not recover soon, Texas might slide into a recession. Relating to the State of Texas, it is estimated that since 2010, additional 2 million barrel of crude oil were produced, reaching a production rate similar to Qatar (Hermann, 2015).

6 The influence of OPEC and Saudi Arabia on the global oil and gas market

To understand the international oil market it is indispensable to be familiar with the Organization of Petroleum Exporting Countries (OPEC). Consisting of eleven members, situated in the Middle East, they are known to be cartel that is dictating the international oil price. Additionally, approximately 40 percent of the world's supply originates from OPEC-members (OPEC, 2014). Due to the variety of use, oil is indispensable in today's global market. However, as a result of decreasing technology costs, new production methods and the re-thinking of the current resource consumption, renewable energy affected oil's market share in OECD countries. Despite a decrease of oil usage originating from the use of solar power in Organization for Economic Co-operation and Development (OECD) countries, the non-OECD country's demand has grown up to 25 percent in the last decade. As the Organization of Petroleum Exporting Countries (OPEC) possesses 77 percent of the international available crude reserves, the dependency of the global oil market on OPEC members is tremendous (Kshirsagar, 2013).

Saudi Arabia is known as one of the most influential OPEC members and therefore the world's largest oil exporter. Saudi Arabia processes 18 percent of the world's proven petroleum reserves by its own. To underline the value of the oil and gas sector for Saudi Arabia, it is estimated that around 50 percent of gross domestic product and approximately 85 percent of export earnings can be traced back to the oil and gas fraction. The underlying spread sheet reinforces the value of the oil and gas production in Saudi Arabia. (OPEC, 2014)

Value of exports (million $)	377,013
Value of petroleum exports (million $)	321,723
Proven crude oil reserves (million barrels)	265,789
Proven natural gas reserves (billion cu. m.)	8,317
Crude oil production (1.000 b/d)	9,637
Output of refines petroleum products (1,000 b/d)	1,841.7
Marketed production of natrual gas (million cu. m.)	100,031
Refinery capacity (1,000 b/cd)	2,507
Oil demand (1,000 b/d)	2,994
Crude oil exports (1,000 b/d)	7,571
Exports of petroleum products (1,000 b/d)	794.0

b/d (barrels per day)
cu. m. (cubic meters)
b/cd (barrels per calender day)

Chart 4: Saudi Arabia: Facts and Figures

Source: (OPEC, 2014)

Due to the significance and the resulting power, Saudi Arabia could support global oil prices by cutting back its own production and creating more demand by reducing the supply on the global energy market. The reasons for their resistance to support the global market might be found in their approach to instill discipline among fellow Opec oil producers and especially to putting oil and gas industries in the United States under pressure. Despite the need of Saudi Arabia to create oil prices to be around 85$ in the long term, resources such as a $700bn reserve fund can resist lower prices for some time. The ability to run deficits for several years is referred to as foreign currency reserves. These artificially created low prices are forcing higher cost producers to shut down and ultimately transfer their market share to Opec producers. Not only Saudi Arabia but also Golf producers like the United Arab Emirates and Kuwait are known have substantial foreign currency reserves.

A different approach at understanding their defensive attitude towards lowering their oil and gas production originates in the 1980s. Back then, Saudi Arabia did reduce the production drastically to increase the demand and therefore boost prices. This measure not only had little effect on the prices, but caused great damage to the Saudi Arabian economy. Back then, Saudi Arabia lost their market share.

According to graph 1 as shown, Opec members such as Iran, Nigeria and Iraq tend to have greater domestic budgetary demands, due a large population-oil reserves ratio.

Despite great oil reserves located in Syria and Iraq, oil production is under great pressure since Isis fighters capture oil wells. By offering a barrel around $30 to $60 to the black market, approximately 3 million dollars are made per day, causing enormous damage to the local and global market.(Bowler, 2015)

Shortly after Saudi Arabia’s King Abdullah has died the price of West Texas Intermediate crude jumped two percent to a value of $47 per barrel. Since his controversial policy that divided the political landscape had tremendous impact on Saudi Arabia’s budged, by driving global oil prices down, it is uncertain if it will be followed up. For now the new king Salman bin Abdulaziz announced to keep up oil production plans (Plumer, 2015a)

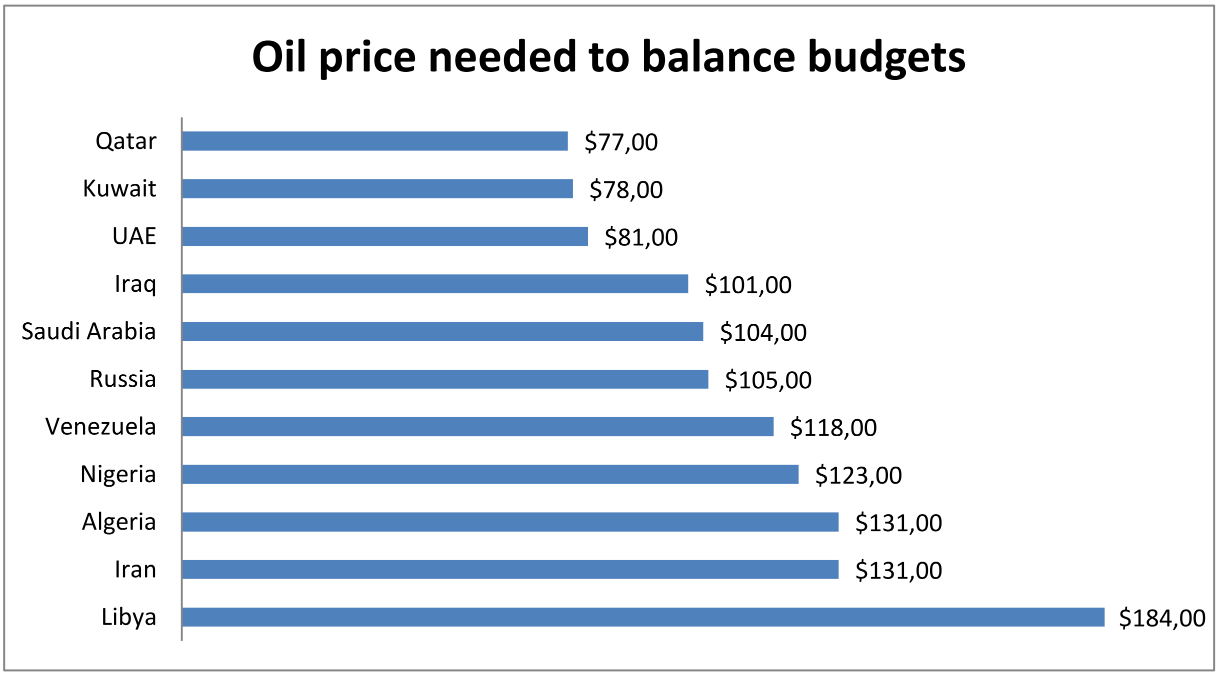

Figure 12: Oil price needed to balance budgets

Source:(Plumer, 2015a)

7 The influence of Russia

With oil and gas being responsible for 70% of the nations export incomes, Russia is known as one of the world's largest oil producers. The dropping oil prices hit Russia's economy and currency “Rouble” hard. According to a study of the World Bank, Russia's economy could shrink by 0.7% in 2015 if oil prices don't recover. In fact, for one dollar price reduction in the oil price Russian economy loses approximately $2bn in revenues (Bowler, 2015).

Geopolitical sanctions would be responsible for Moscow's loss of around $40bn per year according to Russia's finance minister Anton Siliuanov. With Moscow being the major provider for Europe's natural gas supplies, a crisis would have tremendous impact on the global energy market (Critchlow, 2014). It is estimated that in 2015 Russia will face a $80bn deficit in oil exports revenue. If assumed that the current price of Brent crude will be offered at around $60 per barrel over a period of one year, it is estimated that Russia's crude export income will drop about 45%. (Critchlow, 2014)

Due to the support of separatists in eastern Ukraine that led to western sanctions combined with falling oil prices and an interest rate rise, which leads to an incapability to be globally competitive, the Russian government predicted that the economy will sink into recession in 2015. (Bowler, 2015)

Politically, Russia's relationship to Saudi Arabia and Opec members suffered from Russia's tactic support that has been offered to the Syrian regime of Bashar Assad. Despite Opec members reject Russia's accusation of embarking on an all out price war by not reducing extraction and production levels, Saudi Arabia's oil minister Ali

Naimi assured that even with a price level of $20 per barrel production levels would not be cut (Bowler, 2015).

As seen in the two graphs below, it is estimated by EIA that domestic sales of natural gas and crude oil combined for approximately 20 billion dollars in 2013. Furthermore, with a total of 246 billion dollars of crude oil and natural gas exports in 2013, as well as 68% of all exports are ascribable to oil and natural gas, evidence for the dependency of Russia on oil and gas exports is obvious.

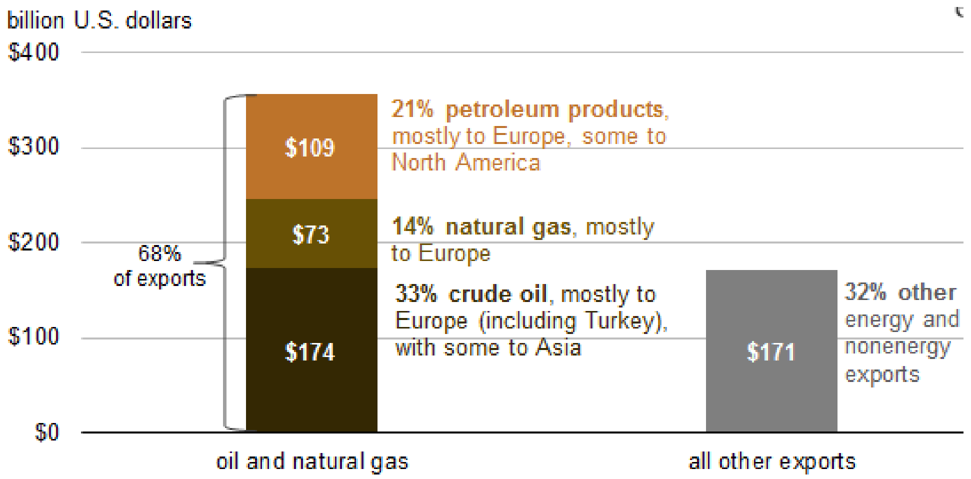

Figure 13: Russia gross export and domestic sales, 2013

Source: (Metelitsa, 2014)

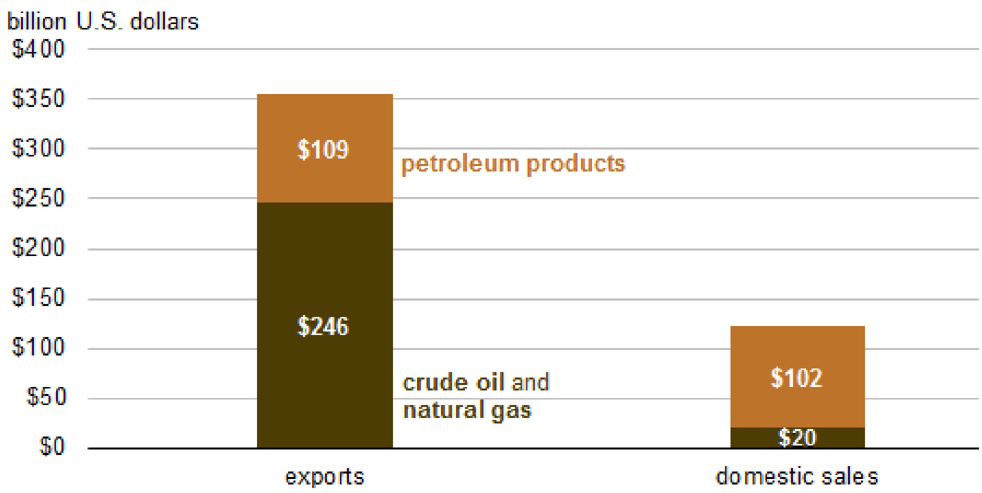

Figure 14: Russia gross export and domestic sales, 2013

Source**:** (Metelitsa, 2014)

8 The Oil crisis

Due to the rising global demand for oil as well as the economical growth of China, the demand was for oil was surging, which resulted in a price increase. Between 2011 and 2014 prices rose to about $100 a barrel. With this favorable starting point, it didn't take long for companies to drill in locations that have not been profitable enough until this day. That's where techniques such as fracking were applied, leeding to a boom in "unconventional" oil production. With fracking being added to oil extracting techniques the U.S. added 4 million extra barrels per day to the global market.

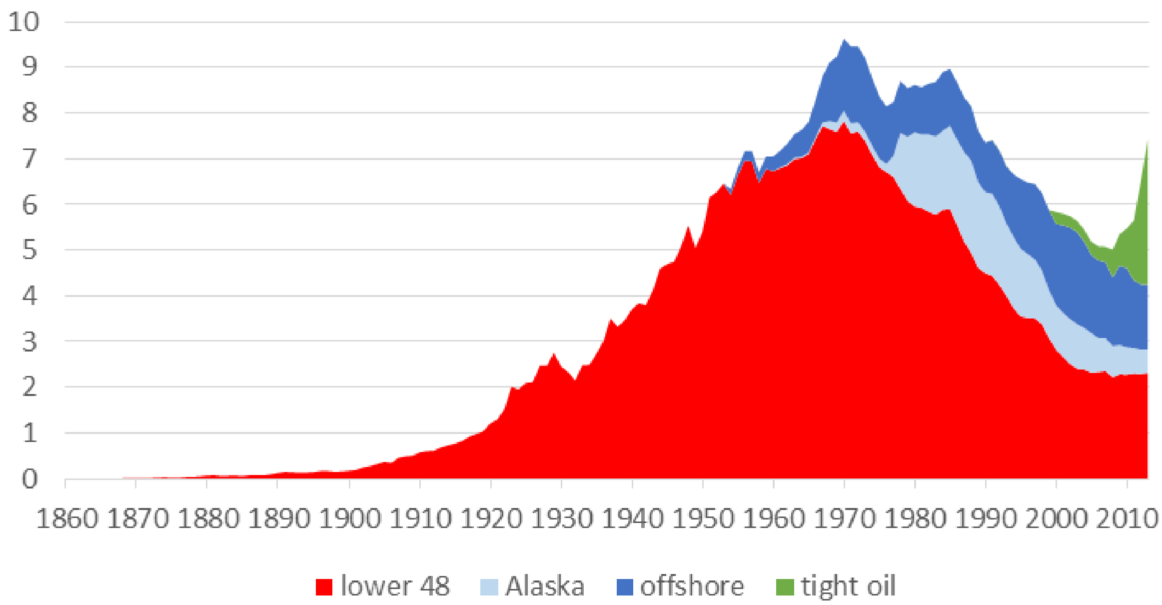

Figure 15: U.S. oil production by source

Source: (Hamilton, 2014)

Surprisingly the enhanced production of the United States did not affect global market as expected. Reasons can be found in different geopolitical conflicts all over the globe suppressing newly created amount of oil entering the market. The civil war in Libya, ISIS threatening Iraq, and U.S: as well as EU sanctions targeting Iraq had tremendous impact on the global market, taking more than 3 million barrels per day off the market. Despite worldwide ongoing conflicts the United States and Canada raised their production and kept satisfying global energy needs.

Due to slowdowns in China and Germany as well as energy efficient technology improving mileage of vehicles, oil demand in Asian and Europe decreased. It can be seen as a combination of steadily rising supply and a weakened demand that resulted in a price drop from $115 per barrel in June to $80 per barrel in November.

Opec’s decision to not reducing their oil production even had a profound impact on Opec members such as Venezuela and Iran. As seen on the graph below, Venezuela and Iran need higher prices to reach their “break-even point”(Plumer, 2015b).

According to Bernsein Research is estimated that approximately one third of US shale projects are only profitable if prices are above $80 (Plumer, 2014). Different sources and analysts evaluate the break-even price for North Dakotas Bakken at around $60-$80. (Gopinath, Banerjee, & Venkatesh, 2014) Estimations and evaluations concerning the capacity and therefore the associated break-even price of shales tend to be very difficult, since Bakken formations are operated by more than 100 companies. Costs of production and extraction differ from each other as well as techniques and geological formations affecting their tolerance for lower prices.

Due to the mentioned factors, analysts inspect the mid-cycle “break even” price which considers that investments of acquiring land and drilling permits were already procured in the past. Despite low prices, the extraction and drilling process can be maintained anyway. This is why falling oil prices are prone to affecting new investments more likely than old ones (Plumer, 2014). According to Reuters new well permits in the United States dropped 40 percent in November 2014. The significance of the characteristic number points indicates how drilling rigs will be operating up to

90 days in the future. Among the affected areas were all top three U.S. onshore fields, including the Permian Basin and Eagle Ford in Texas and North Dakota's Bakken shale.(Hays, 2014)

Saudi Arabia, known as the world's second largest crude oil producer, on the other hand had enough financial reserves to overcome low prices. (Plumer, 2015b)

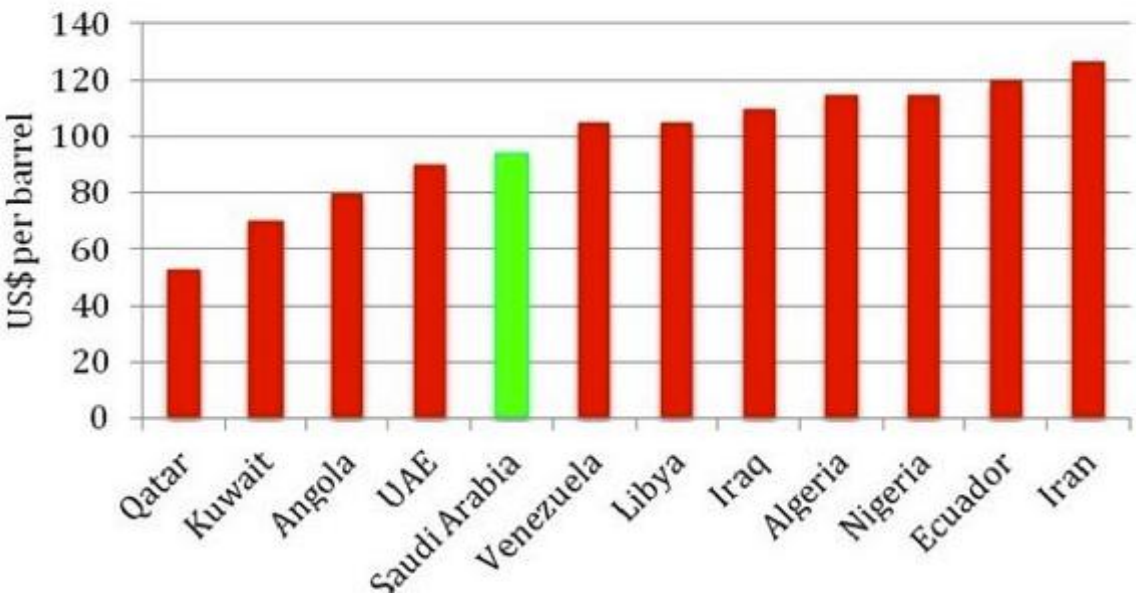

Figure 16: OPEC median budgetary breakeven price

Source:(Real Clear Energy, 2012)

In November OPEC members gathered in Vienna, discussing further approaches on handling this tenuous situation. With the decision of not cutting back the oil production and producing 30 million barrels per day for the next 6 month OPEC didn't meet the global expectations. The price of Brent crude went down even further reaching its minimum of $50 by January. With prices decreasing to a minimum and industries all over the world being forced to stop their production due to a lack of profitability, OPEC members hope to improve their market share ultimately create a price stabilization. (Plumer, 2015b)

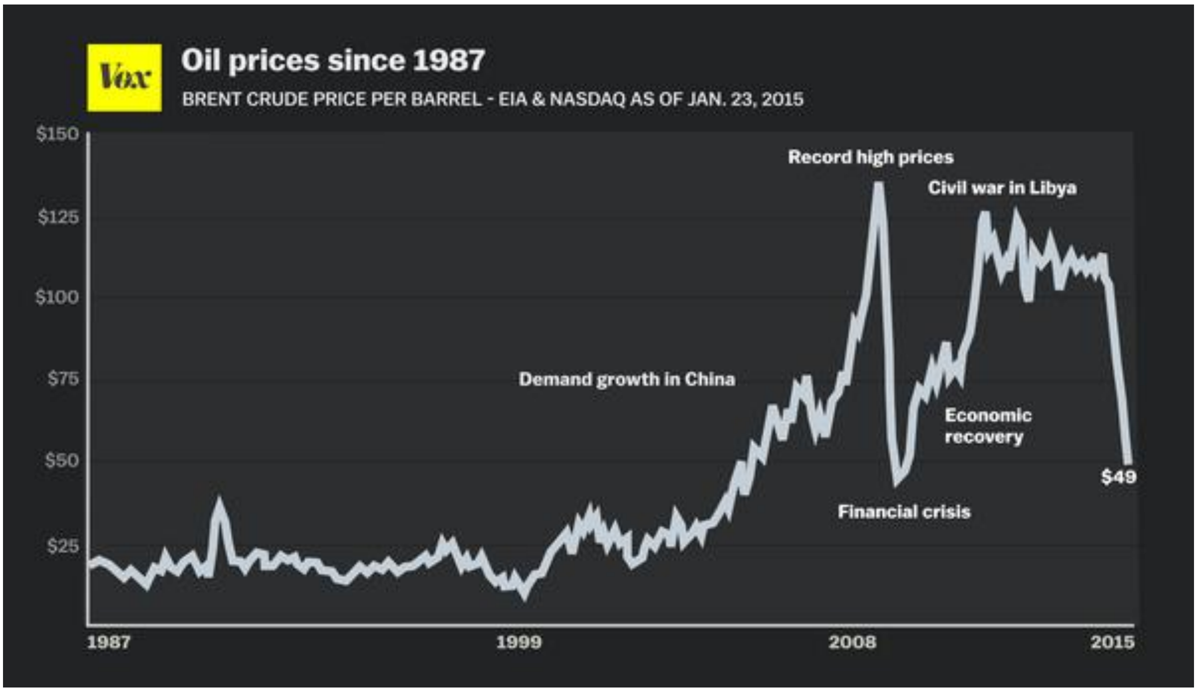

Figure 17: Oil prices since 1987

Source**:** (Plumer, 2015b)

8.1 Future predictions on the oil price

Since there are many parameters that alter in a weakening of the crisis, it is difficult to predict the future situation. If conflicts and wars break out in Libya or Iraq millions of barrel could be hindered to reach the market and be distributed. Saudi Arabia could resign and pull back on their price policy as well as China's economy might revive, increasing global demand (Plumer, 2015b). Companies can also try to costs by improving technology. Shale operators like Continental Resources gained in efficiency from applying new techniques. Multi well pad drilling is a technique where multiple horizontal wells are being drilled from a single spot. By advancing these technologies, cost might be cut to a minimum even though oil prices stay low (Plumer, 2014). With the prevailing ambiguity surveys and studies by Bloomberg Business have been conducted to evaluate the forecasts of experts.

According to Gary Cohn, president of Goldman Sachs Group Inc., the oil price has the potential to continue to decline to about $30 a barrel. With the prevailing surplus, Barclays analyst Miswin Mahesh believes that the oil price might fall even further, reaching the bottom in the near future.

Despite ambiguity many experts pursuit the common belief a rise of the oil and gas price in the future. OPEC's Secretary General Abdell El-Badri, estimates that oil might have the potential to reach $200 per barrel. Due to the lack of investments in new supply, a price rise would be certain. A survey conducted by Bloomberg News, evaluating estimations of 32 analysts and traders, 37% of experts predict a future decline of the oil price. Furthermore, 31% of analysts and traders were certain about a future rise of the oil price. Interestingly, the remaining 32% were not willing to determine a certain toil price trend (Randall, 2015).

By evaluating the survey's results of it is noticeable that there is no distinct outcome of the oil price trend. Not only that there is an almost well balanced amount of proponents and opponents, the fact of almost one third of experts just didn't want to determine a certain scenario is even more striking. Predictions on the time frame of oil price developments would be hypocritical and negligent to be published, when multiple geopolitical factors play an important role. The only thing that seems to be certain is the uncertainty.

9 Conclusion

Oil and gas production through hydraulic fracturing might be more controversial as ever before. The demand for becoming energy independent provided a solid base for hydraulic fracturing to evolve and spread around the United States. Unfortunately the ecological consequences and dangers of this production technique were often disregarded on the behalf of economical growth. Even though advocates of hydraulic fracturing tend to put emphasis on the creation of millions of jobs, it is vital to know that the majority of employees only work part-year. Furthermore, local job creation seems to be only a small percentage of all created jobs, leaving local communities with great responsibilities and problems. To fight this problem the implementation of three steps might lead to hydraulic fracturing being valuable for the local economy. First, it is vital to create space and time for the local economy to adjust. If the pace of production is slowed down until the local economy is able to adapt to the changes, the impact can be minimized. Furthermore, by involving industry in future plans and goals of the local government, infrastructural challenges and requirements can be worked out together. At last, it is mandatory to involve local governments in the decision of finding a designated area. In this way, local governments can plan ahead as well as evaluate the possible consequences on the local economy. By implementing these steps, even an exploiting and somewhat harmful industry can have a positive long-term contribution to the local economy.

The ecological impact of oil and gas productions via hydraulic fracturing, with promoting global warming and polluting water wells, are often generalized by media. With the United States taking the role of the pioneer, the majority of incidents have their origin on American ground. Especially due to media coverage and protests targeting hydraulic fracturing, European countries are mostly against fracking operations. It is undoubtful that contaminations of water reservoirs and high methane emissions can be linked to shale gas extractions, but still the tremendous potential for natural gas serving as a bridge fuel must be taken in consideration.

Shale gas produced my hydraulic fracturing might have the ability to be labeled as a bridge fuel, only if restrictions and laws provide specific regulations that put industries in responsibility of their pollution. Only then, shale gas can take stress off coal productions and be less harmful for the environment.

During my research I was fortunate enough to get in contact with proponents and opponents of hydraulic fracturing. Despite different approaches of looking at this production method they all came to a consensus. The role of hydraulic fracturing must not be to provide energy for independency in the long run, but rather to help promoting and evolving renewable energy systems. By targeting the methane pollution through new technologies and advanced techniques, hydraulic fracturing might be the link to a cleaner future. Therefore fracking has the ability to create space and time for renewable energy to evolve and develop. Tar sands strip mining in Canada or the coal production are unfortunately still part of today's energy production. Despite all negative aspects of fracking, it is might be cleaner than other production techniques that pollute our environment. If taken care of proper disposal of fluids, and the insurance of the quality of casings, fracking can be an alternative.

With the current oil price being on a low, industries have the urge to predict the future trend in order to plan future investments. As seen in the survey of Bloomberg Business there is a great discrepancy between experts and traders. Unfortunately it seems that oil price forecasts tend to lack in substance due to the influence of multiple geopolitical and economical factors. Therefore a forecast of the price's development would not be trustworthy.

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10.1 Table of Figures

10.2 Table of Charts