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RÉPUBLIQUE FRANÇAISE

UNCONVENTIONAL HYDROCARBONS IN FRANCE: PERSPECTIVES OPENED BY NEW TEHCNOLOGIES FOR EXPLORATION AND EXPLOITATION

20 months of research seeking environmentally friendly shale gas

JUNE 2014

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CONSEIL GÉNÉRAL DE L'ÉCONOMIE

MINISTÈRE DE L'ÉCONOMIE
DU REDRESSEMENT PRODUCTIF
ET DU NUMÉRIQUE

INTRODUCTION BY ARNAUD MONTEBOURG

Minister of the Economy, Industrial Recovery and Digital Development

Over the past decade, French industry has fallen into decline; the scope of it is greater than anything previously experienced, and its consequences are disturbing. The French social model has been shaken, our republican pact weakened, our role as a first-ranked nation is compromised along with our capacity to offer our children a better life.

We are racing against time to save our industry and take back ground lost on the international field. The economic urgency means that the government has to carry the battle forward everywhere where competitiveness is at stake, for that is the key question, and includes the costs of the three factors of production: the cost of labour, the cost of capital and the cost of energy.

It is in this difficult context that that the issue of non-conventional hydrocarbons has emerged as one of the means that countries use to positively impact the economic performance of their industries.

On the world scale, the shale gas "revolution" is changing the map of industrial nations and modifying the balance of powers among states. In just five years, the United States, pioneers in non-conventional hydrocarbon extraction (after experiencing its excesses and errors), have regained energy independence and strengthened their industrial position thanks to low energy prices and even diminished green house gas emissions through a dramatic decrease in the consumption of coal, which has been advantageously replaced by natural gas, known to be much cleaner. For ten years, our industry has been under attack by Chinese dumping on labour costs and we have lost big slices of business activity. In the next ten years, we will have to compete with a new low-cost energy contender in: the United States. When energy-intensive industries, such as the chemical, petrochemical or steel industries in France were hit hard, they moved to the United States. In March 2013, a hundred chemical corporations, half of them based in the United States, announced an investment program of nearly 72 billion dollars in the U.S., which should lead to the creation of 1,200,000 jobs through 2020 and generate 20 billion dollars of tax revenue. The relocalisation of the chemical industry is without precedent in the United States. This is the challenge that awaits us.

The question of non-conventional hydrocarbons is essential for France, where the potential for development is significant in economic, geopolitical and environmental terms, according to the International Energy Agency and the *lnstitut Français du Pétrole Energies Nouvelles* which has consolidated available French data for the purposes of this study. If we were to ignore the potential of France's underground reserves, we would deprive our country of considerable growth potential, an unacceptable risk in this current economic crisis. It is better to look to the example of the 1960s, when France developed the Lacq gas fields to the benefit of our industry.

Over 20 months, the Ministry of Industrial Recovery has carried out an in-depth study of the economic potential of non-conventional and the environmental risks associated with different extraction methods. The study gave equal consideration to issues of competitiveness, job creation and the energy transition, raising the specific question of the role of shale gas in the energy mix and the distribution of energy revenues.

To carry out the study, in France and abroad, the Ministry of Industrial Recovery joined forces with experts from the *Conseil General de l'Economie, de l'Industrie, de l'Energie, des Technologies,* the *Institut Français du Pétrole Energies Nouvelles*, the *Direction Generate du Trésor,* the *Office Français des Conjonctures Economiques* and the Roland Berger firm. In addition, the work and analyses were compared to reports provided by the American company eCorp, which has developed new technology, an alternative to hydraulic fracturing that does not harm the environment, propane stimulation; the technique has been used successfully in Canada, in particular. A group of experts travelled to the United States to view an experimental field test of the new technology; their report is published in an annex hereto (cf. annexe,).

The conclusions of this report make it possible to look at shale gas in a new light:

1/ spectacular technological progress now enables extraction of shale gas under conditions that respect the environment scrupulously and non-conventional hydrocarbons can be an ecologically sound alternative. It is now possible to explore for resources while totally respecting the environment and eliminating all forms of underground and surface pollution, through the use of propane gas stimulation. This report, supported by foreign experience, reiterates opposition to hydraulic fracturing, a practice we condemn for environmental reasons, because it requires large quantities of water and chemical additives;

2/ the macroeconomic scenarios based on geological surveys available all suggest very significant potential for growth and the direct and indirect creation of jobs linked with shale gas extraction. In the scenario presented as "probable", extraction of non-conventional hydrocarbons would generate revenues of 294 billion euros over 30 years, whereas the "pessimistic" scenario gives an estimate of about 103 billion euros. The first case scenario would lead to a growth of an average of 1.7 points of GDP per year over the period, accompanied by a reduction of the trade deficit by 0.8 points and of the public debt by 17.5 points over time. The pessimistic scenario projects a growth level of 0.9 points of GDP on average yearly, a trade deficit reduction of 0.4 points average yearly and public debt reduction of 7.5 points annually over time. In regard to jobs, the extraction of non-conventional hydrocarbons should enable the creation of between 120,000 and 225,000 jobs over 30 years; at peak production, there would be 453,000 new jobs, the equivalent of 1.5-2 points off the unemployment rate.

3/ non-conventional hydrocarbons are a transitional energy resource that can carry us through the energy transition to which France is committed, and can help pay for that transition through a redistribution of revenues produced.

By lifting the environmental obstacles to shale gas exploration and reconciling environmental and economic interests in a model for non-conventional hydrocarbon production under public auspices,

this report provides the very answers that public opinion has called for; in regard to experimental research, we can now go forward where our international competitors have already begun to make progress.

Arnaud Montebourg

Forward

20 months in pursuit of eco-friendly shale gas

What does the shale gas challenge mean to France? Can shale gas be part of the energy transition we are committed to? What real economic benefits could be expected? The debate is heated; oil lobbyists oppose environmentalists in such strident voices that it is hard to hear anyone clearly. The most basic questions, however, have not yet been addressed in our country, while elsewhere serious advances have been made.

The Ministry of Industrial Recovery thus determined to carry out a long-term study to shed more light on what is obviously a leading priority on the international scale: a priority with regard to the energy transition first of all, but also to geopolitical concerns and of course a priority with regard to the economy and energy resources.

Throughout 2012, the objective was to understand and hear out all parties, to look abroad for the best and the worst practices in order to avoid repeating the errors of others. It soon became clear that our conviction that hydraulic fracturing is not an option was correct: the massive use of water with chemical additives, as practiced around the world, is a major problem that any technological evolution must overcome. Without technical improvements, shale gas extraction could not happen in France. But at the end of the summer of 2012, the Ministry identified a technology in use in Canada, implemented by an American company, eCorp.

In the fall of 2012, the Minister of Industrial Recovery requested that the *Conseil General de l'Economie, de l'Industrie, de l'Energie, des Technologies* conduct a field trip to the United States to observe experiments with a new technology: pure propane stimulation. This technique involves injecting propane in order to extract underground methane gas, without using any water or chemical additives. This technology seemed promising. At the time of the field study, it had mainly been used in Canada. The purpose of the trip was, on the one hand, to observe this technology – currently promoted by private American interests only – under implementation. The next step was a minute analysis of the advantages and drawbacks of this technology from an environmental point of view and when compared to hydraulic fracturing.

This task force observed the world's first experiment using pure propane, which was crowned with success. The experts turned in a report in early 2013, with the following conclusion: the technology is available and pure propane stimulation can be a credible alternative to hydraulic fracturing. This new technique makes it possible to effectively eliminate environmental damages due to the extensive use of water. However, there is an industrial risk that must be controlled. Propane is indeed an inflammable gas.

The Minister of Industrial Recovery thus asked the eCorp company to perfect a technology that would eliminate the risk of flammability. This was done during the first half of 2013: pure propane

stimulation is the new technology that will make it possible to extract shale gas while respecting the environment. Non-inflammable propane is a well-known gas, used in products including fire extinguishers and medical inhalers.

Throughout 2013, public debate turned to the question of available technologies, for the exploration and extraction of shale gas. The *Office Parlementaire d'Evaluation des Choix Scientifiques et Technologiques* examined the question and drew up a report in June 2013. The Minister then set up a work group calling on technical experts and the support of economic analysts (*Direction Générale du Trésor, Office Français des Conjonctures Economiques*, Roland Berger). An important fact remained unknown in France however: the potential resources available underground. The International Energy Agency publishes reports annually that provide upward or downward estimates of the potential of non-conventional hydrocarbons. These data are approximations: they are mainly based on geological analyses and comparisons with existing basins in operation. Simple mathematics result in figures that, experts are in unanimous agreement, cannot be taken at face value but must be verified on site. For this reason, the Minister of Industrial Recovery sought to have precise information on existing data. France has experience in the extraction of non-conventional hydrocarbons: there are more than 2,000 drilling sites in the Paris Basin, several dozen in the Southeast Basin, two fields where the geology is favourable to non-conventional hydrocarbon exploration and extraction. Patiently bringing together the various data, carrying out analyses and getting second expert opinions, the report resulted in two resource scenarios: one qualified as "probable" and a second as "pessimistic". The Minister asked economists to use these two scenarios to examine relevant questions: how many jobs are at issue? What level of growth can be expected? What will the benefits be for France?

This report is the result of the work carried out for 20 months. Twenty months to discover the keys to what could be, for France, a new environmental and economic revolution. Twenty months to uncover an alternative technology that would make it possible to explore and extract non-conventional hydrocarbons without endangering the environment or contributing to global warming. Twenty months to gather data and affirm economic models. Twenty months to elaborate a policy proposal to bring before to the French people: shale gas, a transitional energy, can finance our transition and contribute to a world where our choices and our daily consumption will no longer present a risk for the planet and future generations.

This report is the fruit of nearly 20 months of work under the aegis of the Ministry of Industrial Recovery, including contributions from the CGEIET[1], the DGCIS[2] and eCorp. The IFPEN[3] provided expertise. OFCE[4] economists went to work to create the scenarios in this report.

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1 Le Conseil général de l'économie, de l'industrie, de l'énergie et des technologies

2 La Direction générale de la compétitivité, de l'industrie et des services

3 IFP Energies Nouvelles

4 Observatoire français des conjonctures économiques

The scenarios presented herein were developed from the data gathered and have been validated by the government, based on underpinning technical hypotheses that were subject to examination and validation by the IFPEN.

CGEIET - ***Conseil General de l'Economie, de l'Industrie, de l'Energie et des Technologies***

The Council on Economy, Industry, Energy and Technologies is under the direct authority of the Minister of the Economy, chairman, and ministers in charge of industry and electronic communication. The Council has jurisdiction in the following fields: economic and industrial development; information technologies, electronic communications, IT, audiovisual technology, postal sector, financial services, banking and insurance, energy, mining and mineral resources and underground resources.

The Council is also authorized to intervene in business matters in all of these fields, in particular those involving associated services, technology, research, training, metrics, industrial safety and technological risks. As needed, the Council is available to ministers overseeing these various sectors.

The Council has written several reports on unconventional hydrocarbons.

DGCIS - ***Direction Générale de la Competitivité de l'Industrie et des Services***

Under the authority of the Minister of Industrial Recovery, Crafts, Trade and Tourism, the

DGCIS is tasked with developing competitiveness and growth of business, industries and services. This includes development of new sectors, in particular services to businesses and individuals, and through the support and distribution of innovation and measures to accompany economic change, with the goals of sustainable growth and employment.

eCorp International, LLC

Founded in 1978 by John F. Thrash, **eCORP** and the companies that preceded it have a long history of experience in the oil and gas industry, in particular in the area of storing and transportation of natural gas, enhanced extraction of oil in classic propane and butane deposits, exploration and production of conventional and unconventional deposits, production of electrical energy and the marketing of electricity and gas.

eCorp was a pioneer in the Marcellus Shale in Pennsylvania, among the first to identify the potential of the deposit. eCorp has acquired positions totaling several million square meters around the world, including both conventional and unconventional deposits.

eCorp is committee-d to environmental protection, and this has led to the creation of service companies, subsidiaries and affiliates such as ecorpStim and eCOREx: **ecorpStim** is specialized in the stimulation of hydrocarbon reserves with pure liquid propane for domestic use and/or with non-inflammable liquid propane, used with low-density proppants. **eCOREx** is specialized in slim hole drilling, specially adapted to the rapid assessment of hydrocarbon reserves. eCOREx's system makes it possible to remove core samples continuously, from the surface to the bottom of the well, and analyze them immediately.

IFPEN - *Institut Français du Pétrole - Energies Nouvelles*

The French Institute of Oil and New Energies is a public research and training establishment. Its scope is international and covers the fields of energy, transportation and environment. Technological innovation, from research to industry, is a the heart of its action.

The IFPEN is tasked with a mission in the public interest, authorized by the government, and focuses on: finding solutions to society's challenges regarding energy and climate by seeking out a sustainable energy mix; the creation of wealth and jobs, supporting French and European business activity and the industrial competitiveness of associated industries.

OFCE - *Observatoire Français des Conjonctures Economiques*

The French Monitoring Agency of Economic Conditions (OFCE) is an independent organization for economic forecasting, research and evaluation of public policy. It is part of the *Fondation nationale des sciences politiques* (FNSP), as part of an agreement between the State and FNSP, dated 1981.

Home to more than 40 French and foreign researchers, L'OFCE analyses most fields of economy: macro-economy, growth, social protection systems, competition, innovation and regulations..

The OFCE developed the SHERPA model (Shale Extraction and Recovery: Projection and Analysis), which provides capacity to stimulate unconventional hydrocarbon production scenarios and to evaluate the impact on the main macroeconomic aggregates.

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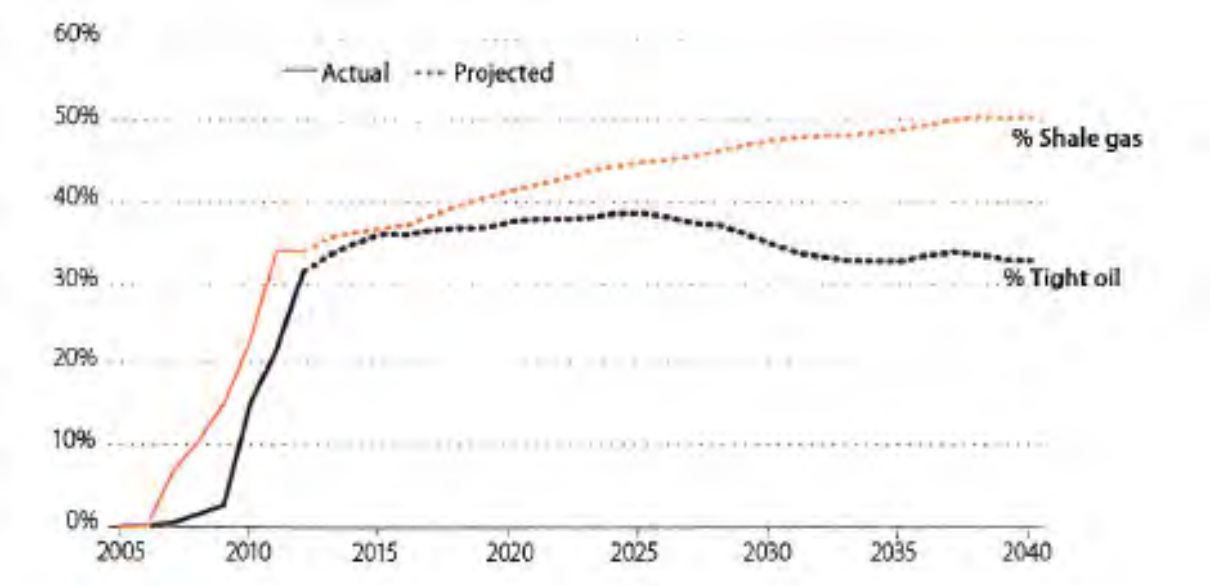
1. SHALE GAS: A MAJOR REVOLUTION FOR THE ECONOMY, ENERGY, INDUSTRY AND GEOPOLITICS. FOLLOWING IN THE FOOTSTEPS OF THE UNITES STATES, MANY COUNTRIES ARE EXPLORING THEIR RESOURCES. FRANCE HAS BEEN AN EXCEPTION.

1.1 The extraction of unconventional hydrocarbons has made a significant contribution to the American economic recovery.

Unconventional hydrocarbons, shale gas and shale oil have risen from 0% to 30% of American production in just five years.

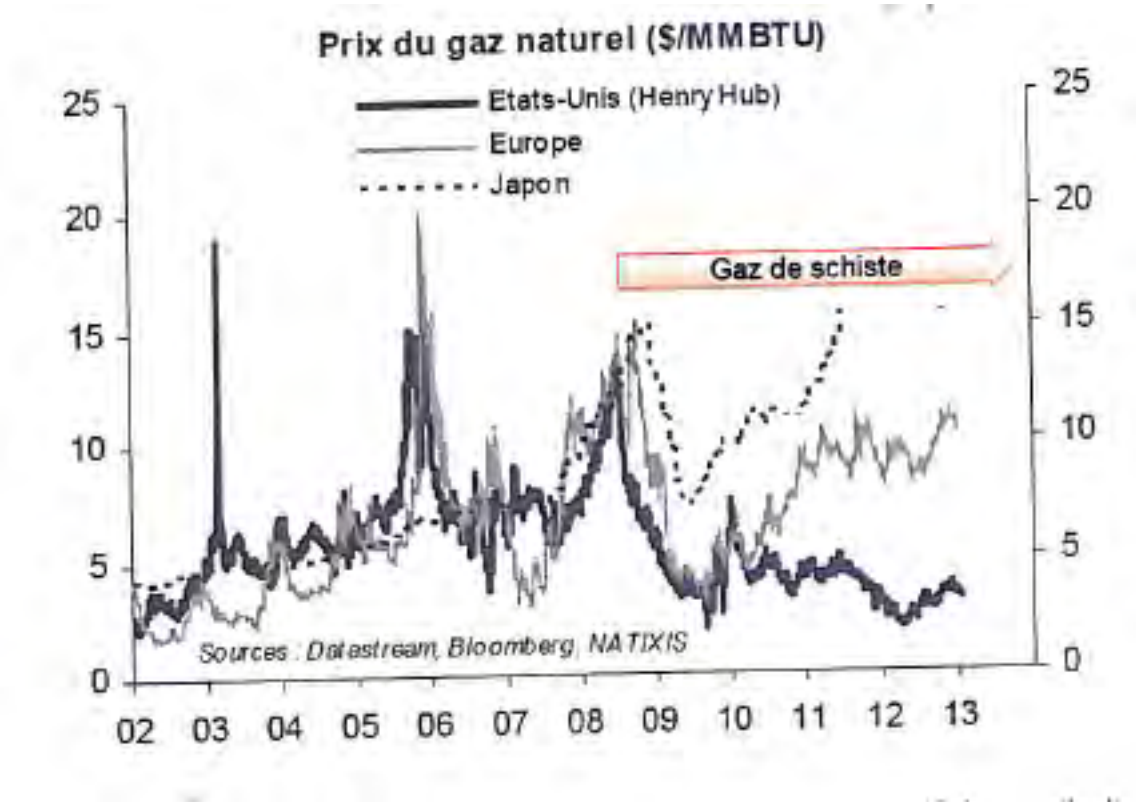


Relative share of shale gas and oil in American production (Source: U.S. Energy Information Administration, Annual Energy Outlook, 2013, http://www.eia.gov/forecasts/aeo/indew.cfm.

Under American mining law, the owner of land is the owner of underground mineral rights as well; this has led to a multiplication of drill sites[5]. In 2012, 48,200 wells were drilled in the US. In the Marcellus Shale alone, in particular in northeastern Pennsylvania and southern New York state, more than 1,000 wells are drilled each year[6].

Extraction of these new oil and gas resources has led to new growth in the production of hydrocarbons, which had previously seemed to be on the decline: oil production had fallen from 11 million barrels a day in 1985 to 7 million in 2005. The United States, which had increasingly come to reply on imported natural gas, now plans to export gas by 202.

The development of this resource has led to falling gas prices in the Unites States: the price today is 4$/MMbtu[7], after reaching a low of 2$. Before the shale gas production boom, the price had reached 12$/MMbtu.



[5] Since 1947, a million wells have been drilled and two million hydraulic fracturing operations have taken pace.

[6] This could not be reproduced in countries with greater population density.

[7] British Thermal Unit (btu, MMbtu is 1 million btu) is the international measurement for natural gas. 1 MMBtu is equivalent to 28 263 681 m3 of natural gas at a given temperature and pressure.

Changes in natural gas prices in Europe, Japan and the USA, before and after the "shale gas revolution" (source: Natixis).

This has given a major edge to many American industries compared to their competitors in Europe, where the price is around 12$/MMbtu.

The recovery of the American steel and chemical industries (refining and petrochemical), and more generally of energy-intensive or high hydrocarbon-consuming industries is a direct consequence of the "shale gas revolution".

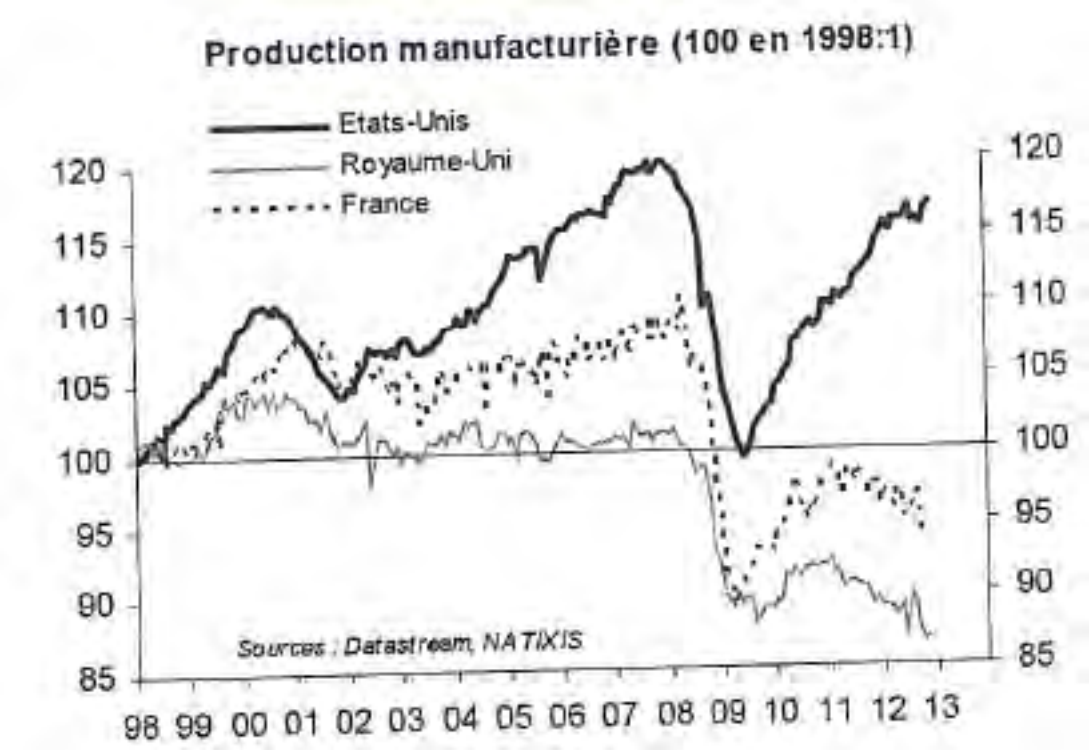
The American steel industry benefitted doubly from the situation: on the one hand, shale gas and oil operations have led to an increased demand for products and equipment using in drilling activities (steel tubing, well casing) and for hydrocarbon transport (pipelines); on the other hand, it has reduced production costs thanks to low-cost energy, as natural gas has replaced coal. Thus US Steel, the largest American manufacturer, increased production of tube products used for drilling and transportation by 17% in 2011[8]. The shale hydrocarbon revolution is responsible for 1/3 of the increase of the American steel market, which is likely to rise by 20% by 2020[9].

The American chemical industry has become dramatically more competitive, thanks to the availability of inexpensive raw materials. In March 2013, nearly 100 chemical industries (half of them based outside the US), announced investment projects in the US for an overall amount of nearly 72 million dollars, which should result in the creation of 1.2 million jobs between 2010 and 2020 and general 20 billion dollars of tax revenues (federal and local)[10]. This movement of relocation of the chemical industry is without precedent[11].

While other factors in addition to the production of shale gas (monetary policy, budget and fiscal measures, exchange rates, labor market, etc.) have contributed to the divergence between industrial production in the United States and in other developed

[8] Miller 2012
[9] White Paper on US Steel Industry – RNCOS 2013
[10] Shale gas, competitiveness, and Net US Chemical Industry Investment: an analysis based on announced projects – Economics and Statistics Department – American Chemistry Council – May 2013
[11] *Impact du developpement du gaz de schiste aux USA sur la petrochimie europeenne*. Note de l'IFRI – October 2013

countries, nonetheless the lower energy prices have played a major role in American industrial recovery since 2009.

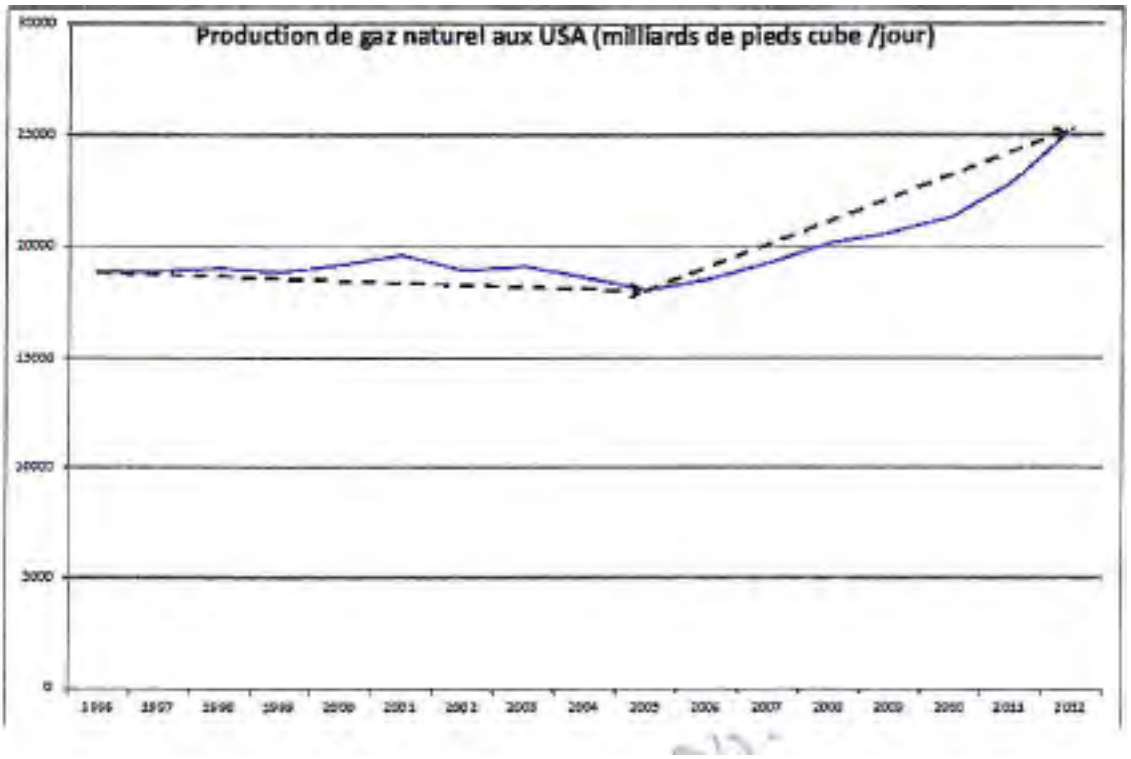


Changes in manufacturing production in the USA (source: Natixis).

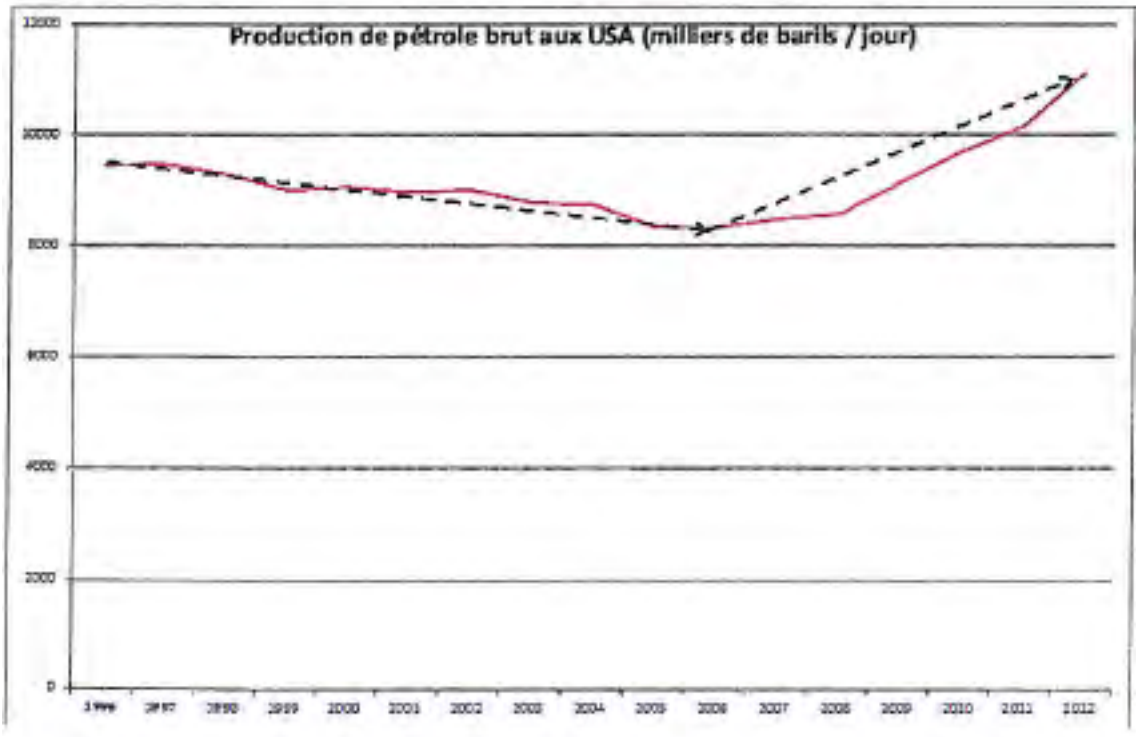
The development of unconventional hydrocarbons has also had a significant geopolitical impact[12], both because of the increased energy independence of the Unites States and in regard to relations between nations[13]. Barack Obama thus told the New York Times in on 19 December 2012*: …this gives us greater freedom of movement to influence developments in the Middle East and more generally around the world (translated from French).*

[12] *Le gas de schiste chamboule la géopolitique*, Régis Genté, *Le Monde diplomatique,* August 2013

[13] According to the Japanese press, quoted in *Les Echos* of 25/09/2013, Tokyo and Ottawa are likely to sign an agreement allowing Japan to import up to 40 million tons of Canadian shale gas per year. This is equivalent to 45% of the LNG imported by Japan in 2012. In order to facilitate negotiations, Shhinzo Abe suggested that measures could be taken to encourage direct Japanese investment in Canadian gas operations (infrastructures and exploration). In particular, Tokyo could contribute to construction of pipelines to transport gas to seaports and also to building plants for liquefaction plants. This potential agreement with Canada comes on the heels of two other agreements with the US, bearing on delivery of 6.7 million tons of shale gas per year to Japan, beginning in 2017.



Changes in monthly gas production in the USA from 1966 to 2012 (source: International Energy Agency)



Changes in monthly oil production in the USA from 1966 to 2012 (source: International Energy Agency)

1.2 In North America, Canada follows in the footsteps of the United States

In North America, the situation in **Alberta** was also examined by the two CGEDD/CGEIET reports devoted to unconventional hydrocarbons in 2011 and 2012. This province of Canada has more than 350,000 wells[15], and each year 15,000 new requests are filed, 60% of which involve horizontal drilling. There are about 800 drilling rigs, 600 of which are in operation (some drilling operations last a few days, others up to a year). The high season for drilling is winter as freezing temperatures ease operations. 60,000 fracturing operations have already taken place, 3,000 of them in the winter of 2011.

Thus, 15,000 wells were drilled in the English-speaking provinces of Canada in 2012.

In **Quebec**, where there was much reticence about hydrocarbon exploration and extraction from source rock, the Petrolia company received authorization in August 2013 to carry out fracturing by injection on the **ile d'Anticosti** in the Gulf of St. Laurent for the purposes of extracting shale oil.

1.3. Several countries, including emerging economies, are seeking to benefit from this opportunity

China, Argentina, Mexico and more recently Brazil have expressed their desire to develop their unconventional hydrocarbon resources.

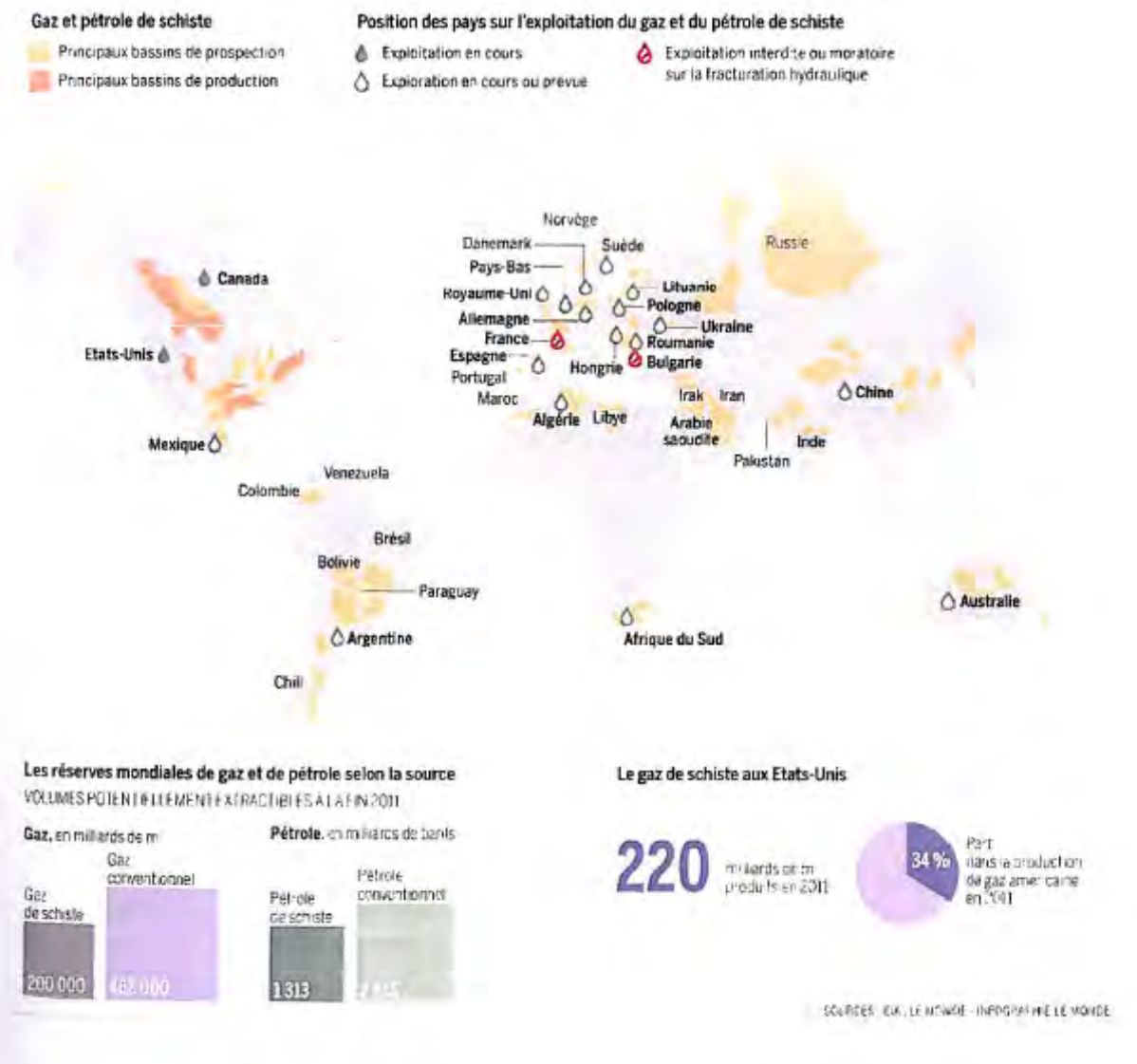
For example, in **Argentina,** in the Neuquén Basin, 220 well have been drilled since 2010, 180 of which produce shale oil[16]. The Nequén Basin is Argentina's main zone of hydrocarbon production (oil and gas). There are also two nature parks in the region,

[15] 150,000 active, 60,000 inactive and 140,000 abandoned
[16] 162 of the 220 wells were drilled by the national company Yacimientos Petroliferos Fiscales

which is on the UNESCO World Heritage List. Agriculture (fruit) is another important economic sector and there is strong growth in tourism.

South Africa, which had established a moratorium that prohibited exploration for unconventional hydrocarbons, lifted that prohibition in September 2012, and should soon be granting new permits, as President Jacob Zuma indicated in his State of the Union speech in February 2014.

1.4. In Europe, Poland and Great Britain are launching incentive policies for exploration and development – the European Union is aligned with this approach



Countries' position on unconventional hydrocarbon extraction (source: "De plus en plus d'Etats partisans du gaz de schiste", Le Monde, 25/08/13)

The **Polish** government has sought to develop this resource to reduce its dependency on Russian gas; today there have been only a few wells drilled (less than 100), a much less intensive campaign than in North America. Progress has been slower, in particular, because of the need to notify residents of the effected areas in due time (a process similar to the *enquêtes publics* held in France). It is also a reflection of the Polish authorities' precautionary approach and objective of setting up monitoring of operational practices. This approach, in a solid framework, and the agreement of a majority of the Polish people[17] that independence from Russian oil is desirable, has meant that the strategy has been able to go forward with little opposition.

Several big players (Exxon Mobil and ENI) recently decided to sell or not to renew their licenses in Poland – because of the disappointing initial well tests[18] as well as administrative red tape – other well-known operators (Total) have chosen to invest there (Chevron in December 2013). Gas has been extracted at a satisfactory rate in Lebork (Lane Energy Poland) and to the west of Gdansk (San Leone); the government has announced the start of commercial operations during 2014[19].

The Polish government would like to speed things up. In March 2014, Prime Minister Donald Tusk announced new regulations that would be more favorable to investors; specifically, there is tax exemption for oil companies producing shale gas until 2020, and the objective is to see 12.5 billion euros investment in the sector over the same period.

In the **United Kingdom**, the government has made development of unconventional hydrocarbon resources a priority. Following two micro-seismic events[20], the British

[17] In a poll carried out in August 2013, the Polish population expressed a favorable opinion of shale gas. Indeed, 72% the population of the regions most concerned by exploration (Pomerania and Lublin), was in favor of extraction, on the condition that measures to protect the environment were implemented. In this case, 60% would accept drilling near their home.

[18] In particular, due to the high levels of clay

[19] Source: *Bulletin Economique Pologne* 31 January 2014: http://www.bulletins-electroniqes.com/actualities/75015.htm. The publication specifies that at this time 51 drilling operations have taken place in Poland, including 11 horizontal drills. Hydraulic fracturing was used for 20 of them. 343 are planned by 2021; it is estimated that 200-250 drills should make it possible to establish the viability of industrial operations.

[20] 1.5 on the Richter scale, in May 2011; 2.3 in April 2011. These levels can be measured by instruments but are rarely perceived and do not cause damage. Statistics indicate that there are 1,000 micro-siesmic events at the intensity of 2-2.9 per day around the world, and 8,000 events registering below 1.9.

authorities suspended operations in order to analyze the situation and define useful precautionary measures, before progressively lifting the interdiction.

In the summer of 2013, Prime Minister David Cameron announced a "new tax regime, which I want to make the most generous for shale in the world." In January 2014, he further specified the tax advantages that local authorities could benefit from if they accepted unconventional hydrocarbon operations on their territory[21]. The government believes this is an opportunity for job creation and a solution to the problem of energy dependence

Work already carried out in the UK on unconventional hydrocarbons brought the British Geological Survey to the conclusion, in June 201", that the Bowland Shales (Lancashire and Yorkshire) accounts for gas resources that may be twice as consequent as the two main American deposits (Barnett and Marcellus) combined.

Analysts estimate that extraction of this deposit could represent an increase of 7 billion pounds of annual GDP for Britain, while reducing greenhouse gas emissions at the same time (substituting natural gas for other fossil fuels that that emit more CO2 in combustion, such as coal). Total E&P UK announced in January 2014 that it would take advantage of this positive environment by entering the sector[22].

In the **Netherlands**, the Minister of Economic Affairs referred to[23] the results of a study[24] indicating the "the country' shale gas reserves could be mined without risk and exploratory drilling is necessary to assess the extent of the resources." Ukraine and Lithuania, like Poland, would like to explore their unconventional hydrocarbon resources in order to be independent of Russian suppliers. In addition, Denmark, Sweden, Romania, Hungary, Spain[25] and Bosnia have recently awarded permits for unconventional hydrocarbon exploration.

Most other European countries are examining the situation, and have not yet stated a definitive position.

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[21] The entire amount of professional taxes, or about 2 million additional euros per site each year.
[22] With the acquitisiton of a 40% ineterest in two exploration and production permits for shale gas in the UK, located in the Gainsborough Trough: http://total.com/fr/media/actualité/communications/20140113-Total-devient-la-premiere-major-a-prendre-des-permis-de-gaz-de-schiste-au-Royaume-Uni-
[23] 26 August 2013
[24] Witteveen & Bos
[25] Four Spanish regions (including Catalonia in January 2014) have voted prohibitions on hydraulic fracturing, which are now being challenged by the central government in Madrid before the Constitutional Court.

The new **German** coalition has taken the position that hydraulic fracturing is unsatisfactory because of potential risk to humans, fauna and flora. In these conditions, the German government has stated that absolute priority must be given to protecting citizens' health and the quality of drinking water. Although a moratorium was mentioned during the 2013 political campaign, there is currently no legislative proposal on the federal level that would prohibit exploration for and extraction of unconventional hydrocarbons. However, the Minister of the Economy has declared that the government will commission scientific studies to evaluate the impact of hydraulic fracturing, calling on Länder, universities and industry. Berlin may also introduce a law requiring environmental impact studies and citizen consultation[26].

At the level of the **European Union**, the Commission published the non-binding Commission Recommendation of 22 January 2014 on minimum principles for the exploration and production of hydrocarbons (such as shale gas) using high-volume hydraulic fracturing[27]. Günther Oettinger, the European Commissioner for Energy, and Janez Potocnik, the European Commissioner for the Environment, have stated several times that the EU will not prohibit hydraulic fracturing and let Member States have a margin for maneuver. The European Parliament held debates at the end of 2013 and in early 2014 on inserting unconventional hydrocarbons in the Directive on environmental impact of certain projects[28]. In a compromise decision with the Commission, the Directive adopted on 13 March 2014 did not make environmental impact studies obligatory for this type of program.

1.5. France is the only country in the world, along with Bulgaria, to have prohibited hydraulic fracturing

The scope and history of the prospection and production of unconventional hydrocarbons if France[29], and the absence of any major incidents over the decades of

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26 http: //www.abo.net/oilportal/top ic/view.do?conte ntl d=2200743&currentpaqe=1

27 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri =OJ:L:2014:039:0072:0078:FR:PDF

28 Such projects are subject to an environmental impact study in all European countries; Frnch regulations al ready call for an impact study at the time of the request for a permit to explore. The Prefect may call for further elaboration of the study if a request for an operating permit is made**.**

29 Exploration and production of hydrocarbons in France have been especially intensive from the 1950s (Lacq) to today. In the 1980s andd 1990s, hundrends of wells were drilled (about 2,000) in the Paris Basin, leading to the discovery and extraction of many deposits, such as Villeperdue (discovered by Triton and operated by Total) and Chaunoy (discovered by Esso, still in operation today, by Vermillion, a company that operated 200 active hydrocarbon wells in the Paris Basin in 2013).

operations[30] in no way predicted the outcry in 2011 when the possibility of exploring for shale gas in Southeast France was made public.

Oil wells drilled in the Paris Basin since the early 1980s (source: industry)

This intense reaction can be attributed to three factors:

- In the 1990s, there was a "simplification" of the process for obtaining a permit for hydrocarbon exploration, with the suppression of the public hearing *(enquête public*) that had previously been a requirement when application was made (over an extended territory); following simplification, the hearing was only required for the preparation of each specific drilling site, at the level of the local authority *(commune)*. Mayors learned from the press that that permits had been issued, and it is understandable that some felt that there was some "deception" involved;
- In the Southeast Basin, oil outcrops near Gabian have been known since Roman times, and the deposit was mined between 1924-1951 by the national *Régie Nationale des Pétroles*. **However, and despite this history, the Southeast Basin has been explores much less than the Paris Basin.** Residents of the area therefore did not have any point of reference in regard to a well-controlled hydrocarbon drilling site. Consequently, they had legitimate fears of seeing the landscape marred by a dense occupation of wells, "American style" and overrun by heavy

[30] including seismic profile acquisition on the Champs Elysées and drilling in proximity to the Château of Versailles.

vehicles servicing the sites; they were vociferous in their opposition;

- The film "Gasland"[31], highly debatable from a scientific point of view[32], strongly influenced public onion in a negative way, whereas hydraulic fracturing had been practice in France at least 45 times without creating any stir.

These strong reactions led to the vote on **French law 2011-835 dated 13 July 2011**, which stipulates that *"exploration and extraction of liquid or gas hydrocarbons by means of hydraulic fracturing of the rock shall be forbidden in France."*

This law created a *"National Commission for the orientation, monitoring and evaluation of techniques for the exploration for and extraction of liquid or gas hydrocarbons" with "the special objective of evaluating environmental risks associated with hydraulic fracturing or alternate technologies and which shall provide public notice of the conditions for implementing experiments, undertaken for scientific purposes only under the control of public authorities."*

French Decree 2012-385 dated 21 March 2012 defined the membership of the Commission, but it has never been convened as the government has not appointed the members.

2. HYDRAULIC FRACTURING HAS BEEN SUBJECT TO CRITICISM, SOME OF IT OUTDATED AND SOME OF IT QUITE LEGITIMATE. THIS TECHNOLOGY IS UNSATISFACTORY IN REGARD TO THE ENVIRONMENT.

2.1 Some criticism has been made of hydraulic fracturing, which is the leading technology around the world for extraction of shale gas and oil

Most of the criticism from shale gas opponents bears on hydraulic fracturing and focuses more specifically on the large **volumes of water and chemical additives.**

31 Documentary by Josh Fox, 2010, http://www.dailymotion.com/video/xtslpi.gasland.news

32 The film famously shows flammable gas coming out of a kitchen faucet; analysis revealed that it was biogenic in origin (from fermenting organic sediment near the surface: swampland, peat, etc.)

In addition, there are fears of the **risk of hydrocarbon leaks,** in particular into the water table; **impact on landscape**; stimulation of **seismicity**; and **disturbance to the local environment** (heavy vehicles, work sites); **methane leaks into the atmosphere.**

Many studies on these different questions have been carried out in the United States and have made it possible to document the relevance of these criticisms and to implement, where necessary, regulations or best practices for industry to respond to these serious problems. In the Untied States,

In the United States, hydraulic fracturing is subject to a number of regulations on the federal level. However, the different States have primacy over the field and can develop regulations that meet their own specific local situations, with regard to the geology and the environment and especially with a view to protecting drinking water. The Environmental Protection Agency (EPA) and the States are working to progressively adapt regulations for a better risk management.

The report "An Overview of Unconventional Oil and Natural Gas: Resources and Federal Actions", published on 15 July 2013 thus pointed out that during the last legislative session, 170 bills were passed concerning the prospection and production of unconventional hydrocarbons in 29 of the 32 States concerned and that 14 of those States had passed laws on natural gas production. In addition, 35 bills were passed in 14 States requiring public information on the chemical additives in use (in all, at the end of 2012, 16 States had made this public information obligatory).

The report also emphasizes that the EPA is actively pursuing a program of studies, evaluation and coordination in this regard.

2.1.1 Risks Associated with the use of chemical additives

Risks associated with the use of chemical additives are of two types:

- Risk that these products will flow up into the water table
- Risks of surface leaks of chemical products.

The American government has carried out a detailed assessment of the incidents reported on drilling sites in the United States. No cases of chemical additives leaching into the water table have been found. Cases of surface leaks (in pipelines, discharge of

fluid flowing back up from a well, excessive discharge into streams during low-water periods) have been recorded in limited number (*see below: 14 cases for tens of thousands of wells).*

American regulations have been strengthened. For example, hydraulic fracturing is now forbidden in deposits that are less than 300 meters below the water table (measurements have indicated that the vericle distance of crack propagation from hydraulic fracturing does not extend beyond 100 meters).

US regulations (Safe Drinking Water Act) also call for a minimum distance between wells and drinking water abstraction sites, as well as between wells and rivers.

However, legislation does leave operators a lot of leeway, both in terms of the products injected and the information they must provide to the publilc in that regard[34].

For these reasons, hydraulic fracturing techniques that are used today are not satisfactory, because chemical additives must be used.

2.1.2 Volumes of water used

The injection of water in oil wells is a common practice to maintain pressure in the deposit and improve recovery rates (the ratio of oil extracted to the oil in the deposit). With conventional deposits, water is injected through wells on the periphery of the deposit and is carried out continuously.

For shale gas, injection of water for fracturing is carried out at certain times only, from the main well.

While the constant improvement of the fracturing technology in North America has made it possible to reduce the quantity of water required and to improve the treatment of waste water, nonetheless, the massive use of water, proportional to the number of operations carried out, raises significant problems of conflict of use.

2.1.3 Risks of hydrocarbon leaks in water tables

[34] American industry has made efforts to improve transparency. As of now, there is an online registry (FracFocus) where companies make public the type of chemical products used in hydraulic fracturing. In May 2012, there were 17,000 declarations from 135 companies. The industry also supported rules on decalrationsin Colorado, Texas and Wyoming. In some cases, the industry goes farther than regulations require and adopts best practices for drilling on the regional level.

This is the area where the greatest number of incidents have been reported in the United States (*cf. in particular the MIT study cited below – 2à incidents reported).* The number of incidents has nonetheless been low, in proportion to the thousands of wells drilled.

In all cases, the origin of the problem was poor construction of the well, with defective ciment in particular. Issues concerning unconventional hydrocarbons are not, in this regard, different from those concerning classic hydrocarbon production.

American regulations have been evolving, especially on the East Coast, now calling for triple casing and double cimenting, which controls the risk; the risk is not specific to shale gas.

2.1.4 Landscape Impact

US mining law, under which the owner of the land has mineral rights below ground, has led to the multiplication of well sites (as many drill sites as there are different owners on top of the deposit).

French mining law – and horizontal drilling techniques – mean that for the most part, drilling can be concentrated on a single pad.

Beyond the initial drilling and fracturing period (a few weeks), the impact on landscape is limited to the wellhead, which is 1.80 meters high in the case of shale gas operations.

Some American landscapes have been "devastated" by the multiplication of verticle wells for oil exploration, the result of lax[35] application of regulations by local authorities; this attitude was generally reinforced by the fact that a large share of the population had no special interest in preserving the landscape.

Such devastation is not necessarily the rule. The case of exploration and operation of conventional hydrocarbons in the Paris Basin, as of the mid-1960s, has shown that such activities can be carried out without damaging the environment and the landscape. Under French law, where the State owns below ground mineral rights and therefore grants a permit for the entire deposit, the multiplication of well heads does

[35] With an aim to boosting hydrocarbon production in the US, the government has in the past granted exemptions to the exploration/production industry: activites concerned were not subject to the Safe Drinking Water Act, the Clean Water Act, the Clean Air Act, the Comprehensive Environmental Response Compensation and Liability Act, etc. In France, and more generally in Europe, such exemptions have never been on the table.

not occur; in the US, a single deposit can be drilled from many different plots of land on the surface. Current technologies make it possible to locate several well heads on one pad (from 10 to 40 depending on the geological characterstics). Regulations can have an impact on well site sprawl that affects the landscape, as seen in the United States; they can also be used to restrict the above-ground footprint by grouping wells on a limited number of pads.

2.1.5 Seismicity

The frequency and consequences of earthquakes are characterized by the Richter Scale, as follows;

Description	Magnitude	Effects	Frequency
Micro	Less than 1.9	Micro quake, not perceived by people.	8,000 per day
Very minor	2.0 to 2.9	Usually not felt by people, but detected/recorded.	1,000 per day
Minor	3.0 to 3.9	Often felt by people, but rarely causes damage. .	49 000 per year
Light	4.0 to 4.9	Noticeable shaking of indoor objects and rattling noises. Significant damage very unlikely..	6 200 per year
Moderate	5.0 to 5.9	Can cause damage of varying severity to poorly constructed buildings. Moderate damage to well-built structures.	800 per year
Strong	6.0 to 6.9	Can causes damage in zones up to 180 km from the epicenter if they are built-up and populated.	120 per year
Major	7.0 to 7.9	Moderate to sever damage across wider areas. .	18 per year
Great	8.0 to 8.9	Can cause serious damage in areas within hundreds of kilometers from the epicenter.	1 per year
Devastating	9.0 and greater	Devastates zones within hundreds of kilometers.	About 1every 6 years

A hydraulic fracturing operation for tapping deep geothermal resources, carried out near a geological fault in Basel in 2006, resulted in a level 3 quake.

In the United Kingdom in 2011, fracturing for shale gas exploration led to level 1 to 2 tremors.

Improved micro-seismic monitoring during the drilling period will prevent the recurrence of such events.

2.1.6 Neighboring areas and worksite problems

Problems such as noise, heavy vehicles, and access roads must be evaluated on a case-by-case basis during impact studies. Drilling and hydraulic fracturing have already taken place in urban areas: useful restrictions can be established by the government with respect to the local environment.

2.1.7 Methane emission and the greenhouse gas effect

The most recent study on methane emissions associated with natural gas extraction was carried out by Caltech, UCLA, Washington State University, the Colorado School of Mines and Texas University. It was published in September 2013 in the Proceedings of the National Academy of Sciences[36]. It shows that **leaks measured at the well sites in the study were quite limited: on the average 0.4% of gas produced.**

In any event, these results are largely below previously cited figures that were as high as 8%[37], which calls into question the very advantages of unconventional natural gas over coal in terms of the environment.

The study cited above shows that leaks observed are, for one half, due to leaks in the compression system and oher equipment; the other half occur during degassing, flaring and downloading[38]. It should be noted in this regard:

- **The use of modern, approved materials** makes it possible to reduce or even eliminate leaks from equipment.[39];
- Leaks associated with degassing, flaring and downloading can be **technically eliminated at an extra cost.**

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[36] Measurements of methane emissions at natural gas production sites in the United States, PNAS, September 2013: http://www.pnas.or/content/early/2013/09/10/1304880110. Carried out on 190 natural gas extraction sites, a significant sample of the US situation.

[37] "High" end estimate in the study by Robert Howarth (Cornell), published in 2011 and widely cited by shale gas opponants. See, for example, http://www.lemonde.fr/planete/article/2012/05/29/climat-1-exploitation-du-gaz-de-schiste-sera it-aussi-nocive-que-le-charbon 1708941 3244.html

[38] Downloading is removing the oil that has accumulated in a gas well

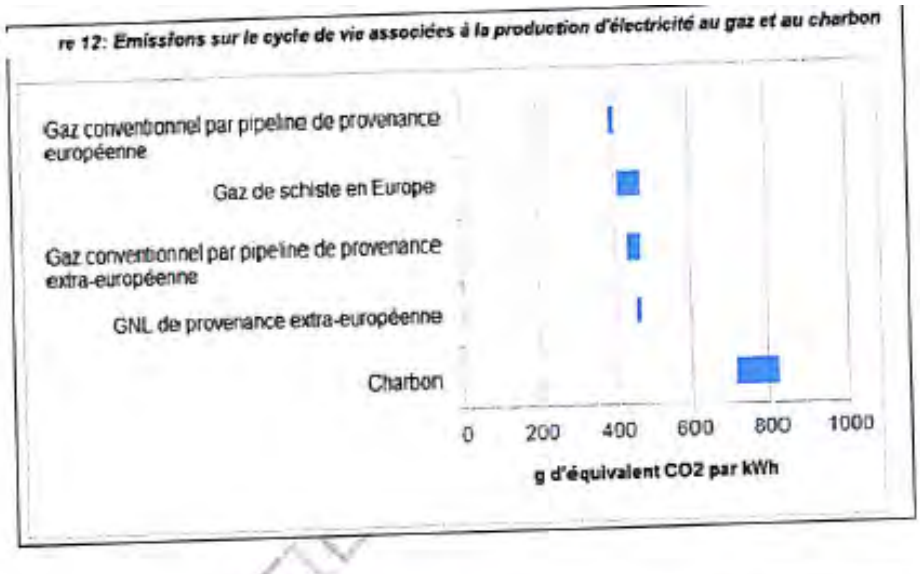
[39] SEAB recommendations, November 201: http://energy.about.com/od/drilling/a/Shale-Gas-Production-Recommendations-From-Seab .htm

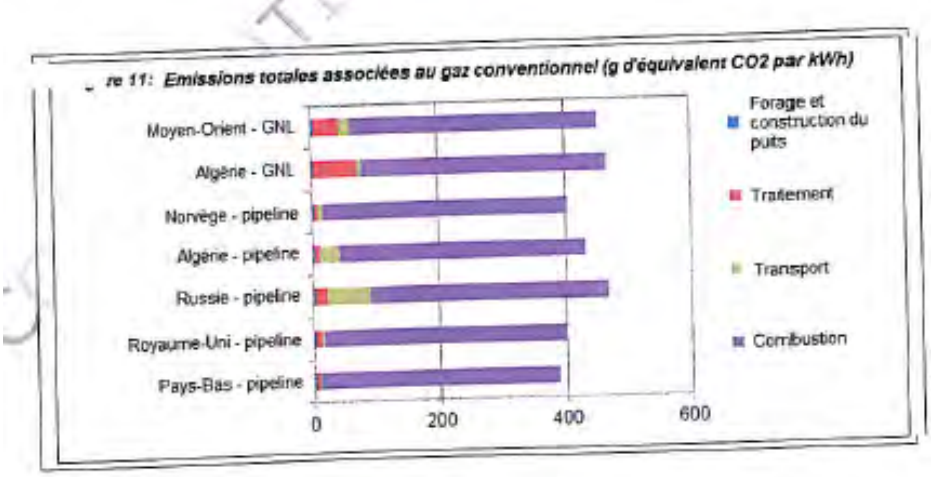
The ket point is that, if gas emissions are not regulated, a gas well may indeed emit methane in as much as it is often more profitable to flare off and degass production rather than set up complicated procedures to recovery quantities that industry qualifies as "marginal". Nonetheless, **99%[40] of these emissions can be eliminated if controls are established by regulations.**

Other emissions are associated with the **distrubtion network** and therefore not caused by natural gas extraction. Thus when gas is transported over long distances, there are leaks in the national network and leaks that occur during international transportation. The reference rate for leaks is 0.9% loss for 500 kms of pipeline. The charts below from a 2012 European Commission study[41] show the different greenhouse gas emissions, for each supply source, highlighting the impacts linked to gas transportation.

[40] Measurements of methane emissions at natural gas production sites in the United States, PNAS, September 2013

[41] Climate impact *of potential* shale *gas production in the EU.* 2012. Source : http://ec.europa.eu/clima/policies/eccp/docs/120815_final_report_en.pdf





2.2 Studies carried out in the United States give a more balanced view on incidents related to hydraulic fracturing

The number of wells drilled in the United States (tens of thousands per year), in places where regulations vary, and by operators of varying quality, establishes a base for the evaluation of the different risks.

MIT, known for its expertise and independence, published a study in June 2011 that summarized several reports[42]. This summary of incidents associated with gas hydrocarbon drilling operations between 2004 and 2009 identifies 43 incidents (tens of thousands of wells were drilled in this period), and classifies them as follows:

[42] The main report was done for the EPA, O2ffice or Ground Water and Drinking Water, 2009.

Nature of the incident	**Number identified in the study**
Contamination of the water table by natural gas	20
Surface discharges on the site	14
Discharges during operations off-site	4
Problems linked with water samples	2
Air quality	1
Eruptions	2

Distribution by category of incident reported in the USA between 2004 and 2009; Source : MIT June 2011

More recently, during a seminar held in in the USA in early 2012[43], the following data, regarding Ohio and Texas, were presented (these data only concern two states, but they cover a period much longer than the MIT study and they also have the advantage of showing – in the Ohio case – evolution over time):

[43] Source: http://www.gwpc.org/sites/defau1Ufiles /event-sessions/05Kell_Scott_0.pdf

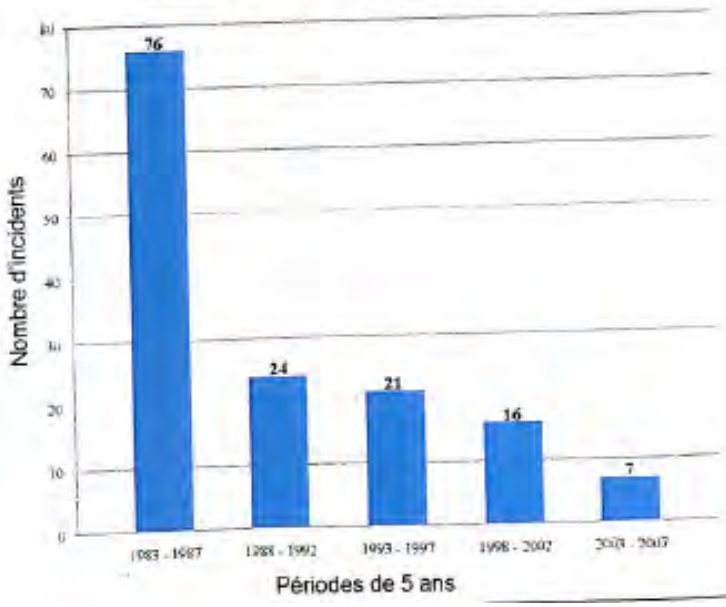
Données présentées à Houston les 23 et 24 janvier 2012 : cas de l'Ohio (1983-2007)

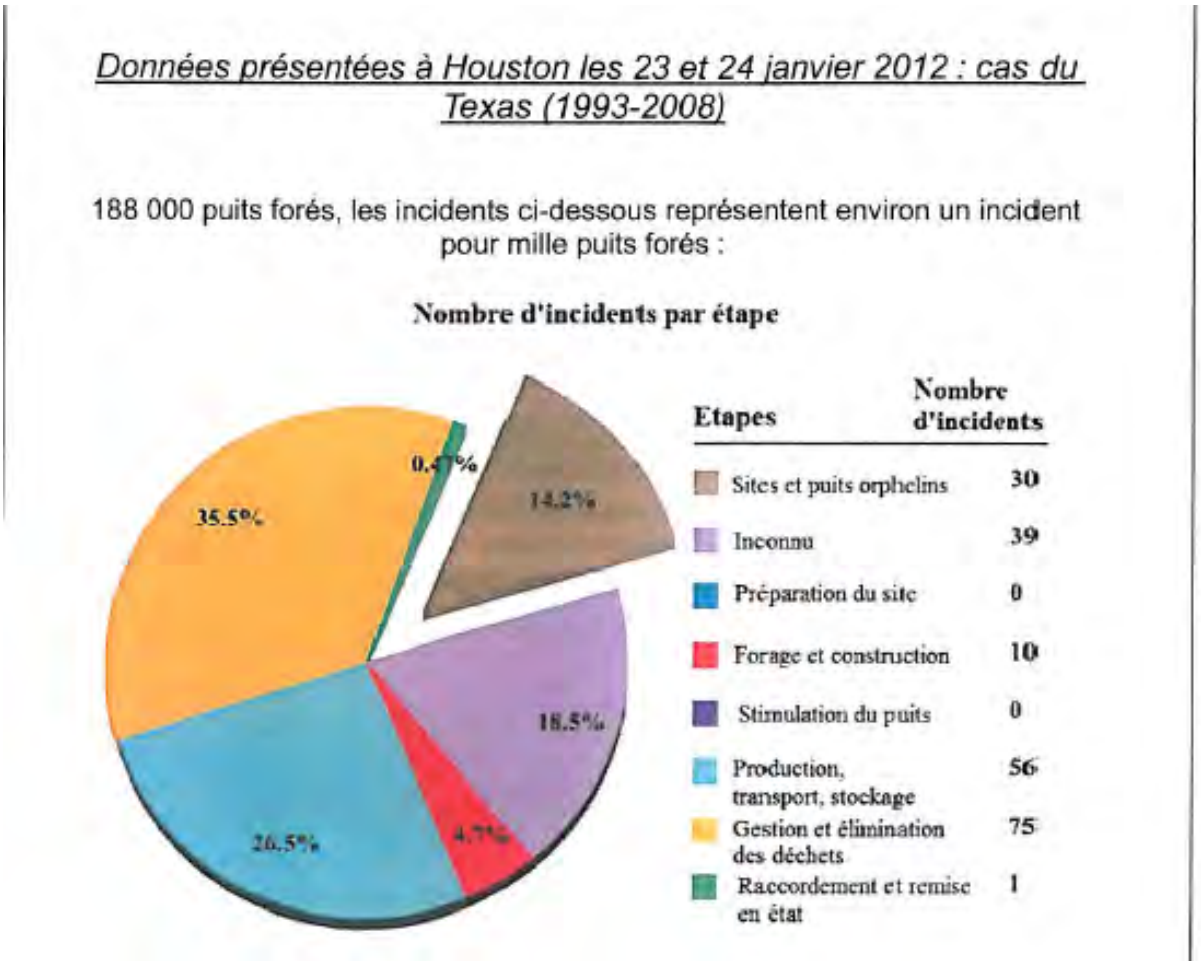
Données récoltées sur plus de 30 000 puits : le nombre d'incidents mentionnés ci-dessous représente donc moins de six incidents pour mille puits :

Nombre d'incidents par étape

Etapes	Nombre d'incidents
Sites et puits orphelins	41
Préparation du site	0
Forage et construction	74
Stimulation du puits	0
Production, transport, stockage	39
Gestion et élimination des déchets	26
Raccordement et remise en état	5

Tendance des incidents sur les puits observés





Two observations emerge from this data:

- The hydraulic fracturing phase was not at the origin of any of the incidents recorded. Therefore, as indicated in all other reports as well:
    - A stricter control of tubing and cimenting phases maked it possible to eliminate sources of pollution of underground water supplies (catgories " drilling and construction" and "orphan wells and sites" can be included in this category);
    - The implementation of stricter monitoring measures for surface operations makes it possible to control spills and discharges, which are the other reported incidents.
- In Ohio, stricter controls by the industry and the government led to a steep decline in the number of incidents.

2.3 Nonetheless, hydraulic fracturing is unsatisfactory, in particular because of the use of big volumes of water and chemical additives

As mentioned in the first section of this report, the documentary *Gasland* came out strongly against hydraulic fracturing and unfluenced public opinion in a very negative way.

Two years later, in August 2012, an IFOP public opinion poll for the newspaper *Le Monde*[44] indicated that:

- 94% of those respondents who were familiar with shale gas stated that it used great amounts of wter;
- 88% of these respondents said it contributed to water table pollution;
- 86% of these respondents said that shale gas extraction involves techniques that are not well controlled.

In summary, "good practices" instated and monitored by authorities can mitigate the risks in question. This is why hundreds of wells (including, in the final phase of deposit production, dozens of hydraulic fracturing operations) have been produced over the past 25 years in the Paris Basin without leaving a mark on the environment and with any lasting harmful effects.

However, grass-roots networks are very active in their opposition to shale gas production in France. Use of large volumes of water and the chemicals added remain problems that have not yet been resolved in regard to hydraulic fracturing technology.

3. TECHNICAL EVOLUTION HAS MADE IT POSSIBLE TO REDUCE THE MAJOR ENVIRONMENTAL RISKS ASSOCIATED WITH EXTRACTION OF UNCONVENTIONAL HYDROCARBONS, IN PARTICULAR BY ELIMINATING THE USE OF WATER AND ADDED CHEMICALS.

[44] See appendix

3.1 Using horizontal drilling techniques limits the surface footprint

The use of horizontal drilling techniques, with lateral drains that may extend beyond 3,000 meters, makes it possible to group up to forty wells together on a pad.

Multi-well pad (source: eCorp)

On the basis of hypotheses of unconventional hydrocarbon production in France[45], it can be estimated that the number of wells[46] necessary for producing all of the deposits in France over a 30-year period would be between 6,000 and 18,000[47]

Counting an average of 20 wells per pad, the 6,000 to 18,000 wells would stand on 300 to 900[48] pads (100 to 200 in the Paris Basin and 200 to 700 in the Southeast Basin).

The figure of 300 to 900 pads throughout the country can be compared to 2,000 sites where drilling has occurred in the last forty years in the Paris Basin, or the 200 well pads that are currently operation in this same area. .

Bringing wellheads together on a single pad is the most efficient way to reduce the surface footprint and landscape impact. Such a pad requires about one or two hectares

[45] Details in the following section

[46] Production is directly proportional to the number of wells, with wells drilled where deposits can provide sufficient production capacity.

[47] Between 2,000 and 4,000 for the Paris Basin, where the underground resources are quite well known and production figures can be estimated, and between 4,000 and 14,000 for the Southeast Basin, where there is more uncertainty.

[48] Between 100 and 200 for the Paris Basin and 200-700 for the Southeast Basin.

(2.5-5 acres) during the drilling phase, and only a few hundred square meters during production (each well head is set in a square that is six to ten meters wide, so a group of twenty well heads in production would be in a rectangle six to ten meters wide and 120 to 200 meters long, or about the space needed for fifteen parking spots in a lot).

Other actions can also be implemented to reduce the environmental footprint on the drilling site: locating sites in former quarries or abandoned industrial sites, installing well heads in natural or man-made depressions, planting a screen of trees, etc.

3.2 New technologies using pure propane stimulation or non-flammable propane without using water or chemical additives

The OPECST[49] report on alternative techniques to hydraulic fracturing, published in June 2013, describes propane stimulation in the following terms:

"Propane stimulation is today the most developed alternative to water stimulation. It is used industrially, which cannot be said for other techniques considered here below, that are in the research or experimentation phase, but have not been deployed on a large scale.

….

The main advantage of propane stimulation is obviously that is does not require water. This means there are no issues of conflict of use or treatment of large amounts of contaminated water.

In addition, propane stimulation can be carried out with using chemical additives in the fracturing fluid. This is what ecorpStim offers. The fluid contains only propane and proppant (sand or ceramic).

In some gas fields, propane stimulation is more productive than water stimulation.

...

95% of the fracturing fluid can be reused, whereas only 30% to 80% of water injected in a hydraulic fracturing operation is recovered.

[49] *Office Parlementaire des Choix Scientifiques et Technologiques*

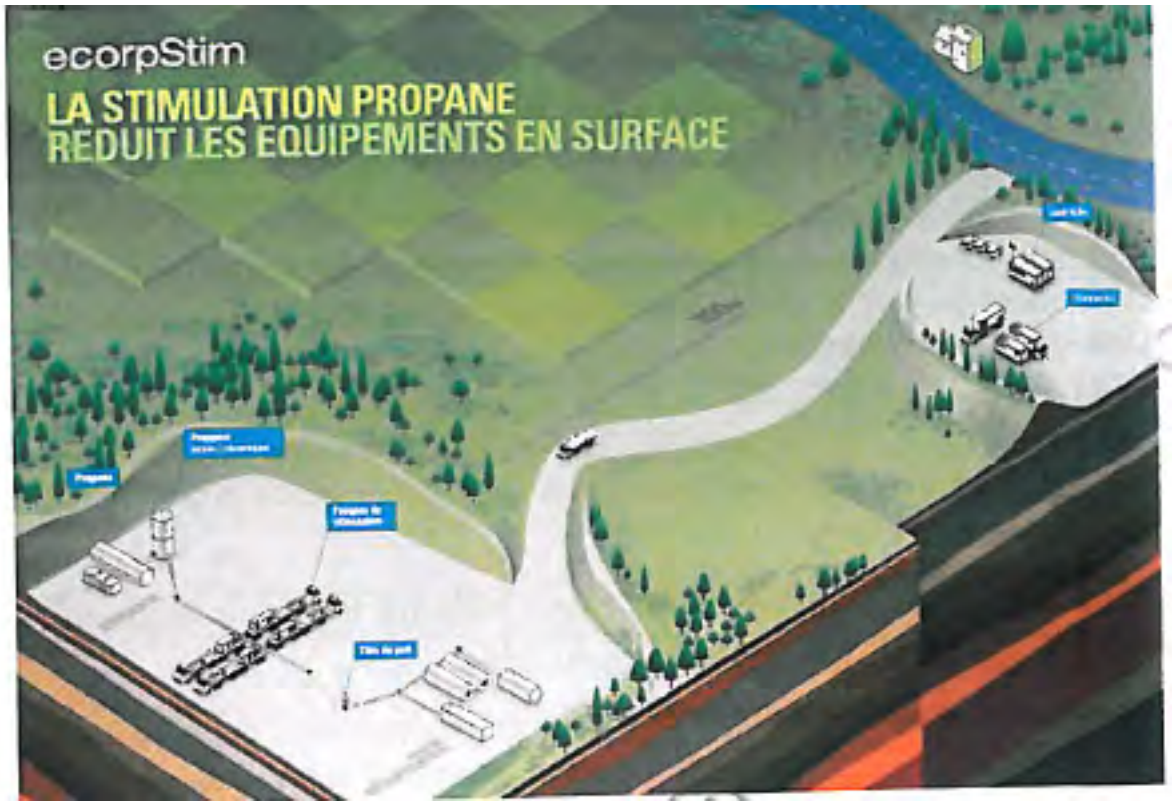
Another advantage is that **propane stimulation requires less equipment on the surface**. This is because the density of propane is lower than that of water (smaller volumes in use) and because so much can be recycled on site, the need to transport fluids is reduced.

...

The main drawback of this technology is that it calls for handling significant quantities (several hundred tons) of flammable propane on the above ground.

...

To reduce the industrial risk, companies using propane set up **automatic safeguard procedures** and provide for **remote control operations,** with several layers of protection (safety valves, embankments, perimeter around the operation zone). The most modern equipment used by ecorpStim requires that only small volumes of propane be stored on site. Furthermore, the company will soon be offering a **technology based on nonflammable propane."**



The Minister of Industrial Recovery has turned toward the American company eCorp, which has developed expertise in propane stimulation technology, in order to undertake an in-depth study of this new technology. The report *(cf. annex)* drawn up by the *Conseil Général de l'Economie, de l'Industrie, de l'Energie et de Technologies* (CGEIET) for the Ministry of Industrial Recovery in February 2013 comes to conclusions that are similar to those of the OPECST. Propane stimulation eliminates the problems associated with the use of water – because it doesn't use any – and reduces logistics flows considerably. It also eliminates the need for chemical additives, another source of concern. The report also underlines the inherent risks of using propane, while pointing out that these risks can be controlled.

To mitigate the risk of flammability, ecorpStim developed a technology in 2013, using **non-flammable propane (NFP)** and presented this technology to the OPECST, which filed a definitive report on 27 November 2013.

NFP stimulation has all the advantage of pure propane stimulation (no water, no chemical additives), and eliminates the risks of flammability associated with propane.

Other advantages are associated with pure / non-flammable propane, as replacing water with propane leads to a reduction:

- Of the footprint on the surface;
- Of the equipment needed;
- Of the number of heavy vehicles;
- Of the volumes of fluids required;
- The time needed to stimulate the rock (between 1/3 and 1/10th).

The reduction of the volume of fluid necessary to carry out a stimulation operation ($1/10^{th}$ to $1/30^{th}$ compared to water) means that an extra layer of tubing can be added to the well, reinforcing the protection of the well, and considerably reducing risk of vibrations against the casing (cement layer) during the stimulation phase.

3.3 Microbores, with propane stimulation limit the surface footprint

Up until now, drilling for hydrocarbon exploration has used bores of the same diameter as production bores: each exploratory well could potentially become a production sight.

eCorp suggests that much smaller bores could be used, "microbores", optimized for exploration. These bores, with a surface opening of 8 ½ inches instead of the 24 inches of a standard bore, would mean that four times less space would be occupied on the surface and logistic flows would also be reduced (as the means required are largely proportional to the diameter of the wellbore.

Conclusions on technological evolutions

The "shale gas revolution" in the USA is not the result of a technological revolution, but of the combination and improvement of two techniques used previously: horizontal drilling and hydraulic fracturing, and their systematic use in source rock hydrocarbon prospection and production.

Fluorinated propane stimulation and micro-drilling are also a combination of techniques that has been tried: propane stimulation has been carried out thousands of times in North America, propane fluorination is a technique that is regularly used in fire extinguishing gases, micro-drilling is a technique that has previously been used in geological prospection for metal deposits.

Because they do not use water and therefore none of the chemical additives associated with hydraulic fracturing, these new techniques eliminate certain concerns (additives leaching into the environment, water use conflict, waste water treatment).

Combining several techniques to elaborate a research program (preliminary prospection) with a minimal environmental footprint, potentially leading to a

prospection/production program with contained impact, is a step forward towards better control on the effects of hydrocarbon prospection on the environment.

Beyond administrative and regulatory measures that are known to reduce risks, the new technology is a game-changer for those who live in the areas potentially concerned with this industry.

4. AT STAKE FOR FRANCE: ISSUES, PHYSICAL DATA, ECONOMIC PERSECTIVE

4.1 Issues

The OPECST report dated June 2 2013 on "alternative to hydraulic fracturing for unconventional hydrocarbon prospection and production" makes the following points:

"Global unconventional hydrocarbon resources have only been roughly estimated. Reserves - which, in relation to resources depend on economic policies in effect - are even more difficult to gauge. That is why the published estimates fluctuate regularly in countries that explore their reserves; for example in Poland, estimates were lowered, and the United States, on the contrary, they recently rose. These uncertainties notwithstanding, it is still widely accepted that the exploitation of unconventional resources is causing a global energy revolution .

...

"The Paris Basin has a potential to produce liquid hydrocarbons. Approximately 2,000 drilling operations have taken place in the area, which is well mapped. These operations indicate that the source rock in the area is prolific.

...

The Southeast Basin (Cevennes, Ardèche) has potential for gas production. This is not really a "Basin" in precise geological terms. It is more complex than the Paris basin and less well mapped since only thirty boreholes have been made."

These observations, and the stirring of public sentiment in regard to hydraulic fracturing, raise the following issues:

- **Physically**, there is good reason to believe that there are very significant resources in France, especially shale oil in the Paris Basin and shale gas in the Southeast basin. Available data make it possible to predict – if the extent of the resource is confirmed – the size of the operations put into play. The extent can only be confirmed – or repudiated – by a program for research and prospection;
- **For the environment**, new techniques for prospection and production may offer the opportunity to take another step forward in containing and reducing the environmental footprint. Furthermore, extra production of hydrocarbons, especially gas, would not reduce the share of non-carbon energies in French consumption, but would provide a substitute for carbon-based resources that are currently mostly imported (energy bill 40 billion euros in the French trade deficit at the end of 2012);
- **Economically,** the impact in terms of jobs, in particular, of course depends on the extent of the resource and the pace of production. It also depends on the use made of the corresponding margin (the difference between the cost of prospection and production and the sale price): the effect on employment is not Physical data.
- **On this basis**, if the decision to reduce uncertainties is made, u-industrial capacities could be brought under the aegis of a national entity with a priority objective of experimenting new technologies available and making a precise assessment of the scope of available resources.

4.2 Physical data that need to be confirmed

4.2.1 Certainties: a thick geological layer over a broad area of the Paris Basin, with a promising "organic content".

The Paris Basin has similarities with the U.S. deposit known as Bakken Shale. It is different, however, with regard to the thickness of the layers of source rock. These layers are divided into three successive strata (shale carton, Domerian and Sinemurian/Lotharengien), with a total thickness of 90 to 160 m, two to four times greater than the thickness of the Bakken shale bedrock. The organic content of the rock in both deposits and maturity level is similar, so expectations are that the French deposit's potential is

significantly higher. The magnitude of existing resources is thus estimated at around 16 billion barrels of oil equivalent (annual oil consumption by France in 2011 was 83 Mtoe[51] of oil products per year, equivalent to 600 million barrels), the proportion of the resource that is actually recovered will depend on the technology used and detailed rock features, particularly in terms of its response to the " stimulus " (features that will not be known until tests have been made).

The Southeast Basin is considerably less explored. What is known from wells that have already been made is that the Lias, which contains the rock, also has a thickness of several hundred meters, rich in organic matter. The extensive network of natural fractures makes it more difficult to assess the sub-soil situation, but other similar areas, including the Neuquén Basin in Argentina, have networks of similar faults.

4.2.2 Uncertainties to be resolved: physical constraints for deposit production and practical means

The OPECST report cited above takes note of the uncertain potential of the deposits. The uncertainly may lead to a re-estimation of the resources, witch may be greater or lesser than we now believe: last year Polish estimates were re-adjusted downwards after prospection began, while in American and the UK, estimates were boosted.

As long as no source rock hydrocarbon drilling has taken place, uncertainties in regard to the ability to produce deposits[52] and the performance of the techniques selected will remain unresolved.

4.3 Expected economic impact of shale gas and oil extraction

4.3.1 Facts and figures

The perspective of economic benefits associated with unconventional hydrocarbon production will be a determining factor in winning over public opinion

As soon as we have a satisfactory response to the question of the technology to be used for extracting unconventional hydrocarbons, the size of expected economic benefits will be a powerful factor influencing public opinion to encourage a project for shale oil and gas exploration in France.

Yet for months, going beyond the environmental issues, shale gas promoters and opponents have been facing off on the question of measuring economic impact. Proponents see a semi-miraculous solution to economic woes in the country, while opponents claim that there are no benefits at all.

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51 Mtoe – Million tons oil equivalent

52 In Poland, some deposits could be produced because of the high clay content of the shale; the presence of clay was known, but the extent and effect had been underestimated.

The work carried out by the Ministry for Industrial Recovery has made it possible to open the debate among independent experts and members of industry on the underpinning technical hypotheses. The hypothesis used to develop the unconventional hydrocarbons scenarios here below were arrived at by consensus.

The working group attempted to be as realistic as possible, and therefore neither minimized nor maximized the expected benefits.

The macroeconomic impact of unconventional hydrocarbon extraction will depend first of all on the actual level of recoverable resources. With the help of public experts and the comparison of public and private data bases, the scenarios were built.

The economic impact of unconventional hydrocarbon extraction is directly linked to the volume of production.

Estimation of the production level depends on the ex ante assessment (in the absence of test drills) of the potential resources on the known geological characteristics of the field and the resources that are supposed to be recoverable, given various constraints (geographic, environmental, technical, etc.).

Public data on unconventional hydrocarbon resources comes from the International Energy Agency (IAE). The data is based only on information that is publically available, and the IAE itself recognizes that the data is often incomplete and approximate. This is the case for data on French resources in particular. Public data is calculated based on known geological data and by extrapolation from basins already in play. At every update, the potential for unconventional hydrocarbons can be adjusted upwards or downwards, in relation to improved information on the basins in exploration (case of Poland or Great Britain recently) or as theoretical models of extrapolation are modified.

The most reliable data is from private operators that invest to generate information with high added value; these operators have exclusive access to the data at east during the upstream phases of a prospection/production operation. Test wells that yield this exclusive information – depth, formations, drill speed, core samples, etc – are designed to collect samples through tight holes.

In order to fill out the data on potential in France, the Ministry of Industrial Recovery has brought together public and private experts to concatenate existing databases and make them more reliable.

In addition to taking geological characteristics into account17, the hypothesis that were built include results for the most recent technological developments which increase well yields significantly: multiplication of lateral drains, substantial extension of lateral drains, more fracturing through lateral drains, use of new proppants(sand, ceramic, etc.)[54].

[17] HIS, an economic analysis firm, thus underlined in a recent report that Cabot was able to double production levels per well in the Marcellus Shale by lengthening the horizontal bores and carrying out more fracturing phases on each lateral drain.

[54] Publication presented at the SPE annual technical conference and exhibition that was held in New Orleans from 30 September to 2 October 2013, on the subject of increased yields linked to new ceramic proppants.

The OFCE used all of this data to build its hypothesis and undertake macroeconomic projections, using the Sherpa model.

Production hypotheses used for the scenarios were enlightened, prudent and realistic.

Two scenarios were built for shale gas and oil production, one designated "probable" and the other "pessimistic". The difference lies in the number of wells drilled and so in the hypothesis of the technically recoverable resources.

Shale gas scenarios (mainly in the Southeast Basin)

NB – on units of measurement: Billion cubic feet, BCF, and Trillion cubic feet, TCF, are used to measure volumes of natural gas. For commercial quality gas, the conversion factor is 1 G.m³ = 35.3 BCF.

In the "probable" scenario, the production of shale gas is 67 Tcf over 30 years (49% of the technically recoverable resources) whereas it is only 19Tcf in the "pessimistic" scenario (14% of technically recoverable resources).

Supposing that French gas consumption remains constant over the period, this production would be equivalent to 170% of our average gas consumption over 30 years in the "probable" scenario, and 50% in the "pessimistic" scenario.

Depending on the scenario, drilling stops 15 or 17 years after production begins; this corresponds to peak production time.

In both scenarios, the final production per well (or Estimated Ultimate Recovery – EUR) varies from 3.5 Bcf to 5 Bcf.

The difference between the two scenarios is the number of wells bored (lateral drains); 14,112 in the "probable" scenario, for 700[55] pads19, and 4008 in the "pessimistic" scenario, for about 200 pads.

Shale gas scenarios (mainly in the Paris Basin)

In the "probable" scenario, the production of shale oil is equivalent to 2 Gbbl over 30 years (12% of the technically recoverable resources), and 1.07 Gbbl in the "pessimistic" scenario (6% of the technically recoverable resources)[56].

[55] Counting an average of 20 wells per pad

[56] Because of the viscosity of oil and its capillary attraction, oil does not flow up as easily as gas from fractures created in the rock. Therefore, the percentage of recoverable resources is lower than for gas.

Supposing that French oil consumption remains constant over the period, this production would be the equivalent of 13% of average French oil production over 30 years, in the "probable" scenario; and 6.5% in the "pessimistic" scenario.

Drilling stops 21 years after the beginning of production. Shale oil wells decline more rapidly than gas wells, drilling must continue over a longer time to maintain production over 30 years.

Estimated Ultimate Recovery (EUR) per well is 500,000 bbl in the two scenarios.

The main difference in the two scenarios is the number of wells drilled (lateral drains), which is 4,000 in the "probable" scenario, for 200 pads, and 2,100 in the "pessimistic" scenario, for about 100 pads.

4.3.2 The results

The economic benefits that might be expected from the production of unconventional hydrocarbons in France are significant, and could make a considerable contribution to France's economic recovery.

Hypotheses used in the OFCE model

The projections were made using the hypothesis that the "shale oil and gas sector" is 66% national, and the real discount rate (exclusive of inflation) is 4%.

In addition, the real prices of gas and oil (exclusive of inflation), are supposed to be constant over the projected period.

Lastly, the hypothesis supposes that revenue raised through shale gas and oil production is distributed for one-third in public investment for the energy transition, one-third for reduction of compulsory contribution rates for businesses and households, and one-third for the reduction of public debt.

Benefits expected from shale gas production

According to OFCE projections, based on two scenarios validated by the IFPEN, shale gas operations would raise revenues of 224 billion euros[57] (NPV) over 30 years in the "probable" scenario; the "pessimistic" scenario predicts 66 billion euros[58].

[57] 300 billion dollars

[58] 85 billion dollars

In the "probable" scenario, the increase in GDP would be 1.3% average over 30 years (3% at production peak in year 15); in the "pessimistic scenario the increase would be 0.7% (1.8% at peak production in year 17). Whatever scenario is used, the increase in GDP would not be linear. The boost is smaller during the first five years of production, and then rises steeply up until peak production (between the 15th and 17th year depending on the scenario), before dropping off after the peak.

The commercial balance would be improved by 0.6 points average over 30 years in the "probable" scenario (1.35 points of GDP at peak production) as nationally produced gas replaces imported gas; by 0.3 points of GDP n the "pessimistic" scenario (0.75 point at peak production).

Lastly, public debt would be reduced by 14.5 points of GDP at the end of 20 years in the "probable" scenario, and 6 point of GDP after 15 years in the "pessimistic" scenario.

Benefits expected from shale oil production

OFCE projections based on 2 scenarios validated by IFPEN show that shale oil production would raise revenues (NPV) of 70 billion euros[59] over 330 years in the "probable" scenario, and 37 billion euros[60] in the "pessimistic" scenario.

The increase in GDP would be 0.4% on average for the "probable" scenario (0.5% of GDP at peak production in year 10) and 0.2% in the "pessimistic" scenario (0.3% at peak).

The balance of trade would be improved by 0.2 point of GDP (0.25 points at peak) in the probable scenario, as nationally produced oil replaces imported oil; in the "pessimistic" scenario, 0.1 points of GDP (0.12 at peak)

Lastly, public debt would be reduced by 3 points of GDP at the end of 20 years in the "probable" scenario (and 1.6 points of GDP in the "pessimistic" scenario).

In summary, the production of unconventional hydrocarbons in France (shale gas and oil), would generate income over 30 years – RPV – of 294 billion euros in the scenario considered "probable", or 103 billion euros over 30 years in the "pessimistic" scenario.

At the same time, such production would lead, over 30 years, to an average increase of 1.7 points of GDP, a reduction of the trade deficit of 0.8 points of GDP and a reduction of public debt of 17.5 points of GDP in the scenarios considered "probable". In the "pessimistic" scenario, the increase of GDP would be 0.9 points, the reduction of the trade deficit would be 0.4 points and the reduction of public debt 7.5 points in thirty years' time.

[59] 89 billion dollars

[60] 48 billion dollars

Projections for job creation are significant and could even be re-evaluated upward

The estimate of the number of job created directly by hydrocarbon production is fairly straightforward, as these jobs are closely linked to drilling new wells. Once the drilling period is finished, direct employment quickly falls off, while indirect unemployment persists.

Thus, in the "probable" scenario, producing shale gas in the Southeast Basin alone would require drilling about 14,000 lateral drains, creating about 60,000 jobs directly at production peak in year 15.

In addition, the size of investments would lead to a significant ripple effect on the rest of the economy, creating indirect employment. The number of these jobs would depend on the hare of intermediate consumption that had to be imported (drilling equipment, specific types of steel, specialized geologic surveys, etc.) for producing shale hydrocarbons.

Induced employment is more difficult to calculate, because it depends on how revenue is distributed and requires complex calculations with many factors. Therefore, economic forecasts[61] do not generally take induced employment into account, which mechanically leads to an underestimation of economic results.

In the OFCE simulation (where standards factors were used at this stage), revenue spending had a positive impact on employment, through the shaper competitive edge gained by businesses (linked to lower production costs), public investment in the energy transition, or through the increased demand associated with higher purchasing power resulting from lower household taxes.

According to OFCE forecasts, overall shale gas and oil in France would enable the creation of 225,000 direct, indirect and induced jobs on average over 30 years in the "probable" scenario. At peak production, year 15, the number of job created would be 453,00022. In the "pessimistic scenario, 120,000 direct, indirect and induced job would be created

[61] such as the one made by Roland Berger Strategy Consultants, see annex

Evaluation of the economic impact of unconventional hydrocarbons in France using Sherpa model simulations (OFCE) from MRP data bases validated by IFPEN					
Scenarios	Estimated revenues (BN of euros NPV)	Expected impact on average over 30 years at peak production …			
		… GDP (added pts)	Jobs (added units)	Balance of trade (added pts GDP)	Public debt (reduction pts GDP)
Shale gas "probable" Scenario (total production 67 Tcf over 30 years)	299 BN $ over 30 years (10 BN $ per year) (299+89=388)	1.3 pts GDP average over 30 years 3 pts GDP at peak (year17)	190,00 average 400,000 at peak (year 17)	0.6 points GDP average over 30 years 1.35 pts GDP at peak (year 17)	- 14.5 pts GDP at the end of 30 years
Shale gas "pessimistic" Scenario (total production 19 Tcf over 30 years)	85 BN $ over 30 years (2.8 BN per year)	0.7 pt de GDP on average over 30 years 1.8 pt GDP at peak (year 15)	100,000 jobs on average over 30 years 220,000 at peak (year 15)	0.3 points GDP on average over 30 years 0.75 pts GDP at peak (year 15)	-6.0 pts at the end of 15 years
Shale oil "probable" Scenario (production 2 Gbbl over 30 years)	89 BN $ over 30 years (3 BN per year)	0.4 pt de GDP on average over 30 years 0.5 pt GDP at peak	35,000 jobs on average over 30 years 53,000 at peak	0.2 points GDP on average over 30 years 0.25 pts GDP at peak	-3 pts de GDP at the end of 20 years
Shale oil "pessimistic" Scenario (production 1.07 Gbbl over 30 years	48 BN $ over 30 years (1.6 BN per year)	0.2 pt GDP on average over 30 years 0.3 pts GDP at peak	20,000 jobs on average over 30 years 30,000 at peak	0.1 points GDP on average over 30 years 0.12 pt de GDP at peak	-1.6 pts de GDP at the end of 20 years

Sources: Sherpa-OFCE calculations, IFPEN

While these figures are significant, they could be re-evaluated upward

Indeed, the *Direction Générale du Trésor* (French Treasury) launched a simulation using publically available data[63]. This projection leads to a ration of job creation to unit of production (8.6 jobs for 1Bcf of shale gas produced) This simulation would lead to the creation of 100,000 jobs by the end of a 20-year period.

Using he same job creation ratio and the scenarios drawn up in this report, validated by the IFPEN, an initial estimate of the number of jobs created reaches 580,000 jobs in the probably scenario, and 160,000 in the pessimistic scenario – figures well above those cited here above.

Lastly, if we look at the most recent American studies, in particular the one carried out by the ICF[64] it appears that between 30,000 and 60,000 jobs (direct/indirect/induced) are created for each added Bcf/day of shale gas or oil produced. Thus, all things being equal, with the lower estimate (30,000 jobs for each Bcf/day) and applying it to the production scenarios for just shale gas in France, we calculate the creation of 560,00 jobs (direct, indirect and induced) for the "probable" scenario and 159,00 for the "pessimistic" scenario[65].

These estimates are convergent.

OFCE MRP Scenarios	*DG Trésor* Extrapolation IFPEN scenarios	ICF (US) Study Extrapolation IFPEN scenarios	Roland Berge Strategy Consultants Public Data
225,000 (probable scenario)	580,000 (probable scenario)	560,000 (probable scenario)	180,000 at peak (high end scenario)
120,000 (pessimistic scenario)	160,000 (pessimistic scenario)	159,000 (pessimistic scenario)	60,000 at peak (mid-range scenario)

63 Starting from the hypothesis that shale gas production would represent 4,000 Bcf over the 20-year period. See study in annex.

64 Report published by the American Clean Skies Foundation, based on an analysis carried out by ICF International: "Tech effect: How innovation in oil and gas exploitation is spurring the US economy", October 2012.

65 The "probable" scenario corresponds to 67,000 Bcf, or maximum annual production of 18.7 Bcf/day for 14,000 wells – the "pessimistic" scenario corresponds to 19,000 Bcf, or maximum annual production of 5.3 Bcf/day for 4,000 wells.

Other major economic impacts linked to unconventional hydrocarbon extraction cannot be estimated exactly at this time but should be given consideration nonetheless.

A certain number of economic impacts linked to the production of French shale gas and oil cannot be calculated precisely at this stage, but some examples serve as indicators.

In the OFCE hypotheses, a third of the revenues generated by unconventional hydrocarbon operations would be used for debt reduction. However, the model does not take into account the potential effects of lowered public debt on sovereign interest rates; the effects are difficult to measure, but could be significant.

In the model used, it was supposed that job creation was at zero at the outset of operations and returned to zero at the end of the period in question. Yet expertise developed by French companies throughout this period will continue to produce effects and enable French business to occupy an advantageous position in an expanding world market.

Lastly, the decision to extract unconventional hydrocarbon resources will make it possible to maintain jobs in some sectors, especially petrochemical refining, that are under growing competitive pressure from the United States[66].

66 See the IFRI memo "Impact of shale gas development in the United States on European petrochemicals", October 2013.

Scenario	Resources	Impact expected	5 years	10 years	15 years	20 years
Probable	Shale gas	GDP EMPLOYMENT	0.3 51,000	1.9 245,000	3.0 392,000	1.2 195,000
	Shale oil	GDP EMPLOYMENT	0.4 29,000	0.5 52,000	0.5 52,000	0.4 42,000
	TOTAL	**GDP** **EMPLOYMENT**	**0.7** **80,000**	**2.4** **297,000**	**3.5** **444,000**	**1.6** **237,000**
Pessimistic	Shale gas	GDP EMPLOYMENT	0.3 46,000	1.5 175,000	1.7 195,000	0.3 35,000
	Shale oil	GDP EMPLOYMENT	0.2 16,000	0.3 28,000	0.3 28,000	0.2 23,000
	TOTAL	**GDP** **EMPLOYMENT**	**0.5** **62,000**	**1.8** **203,000**	**2** **223,000**	**0.5** **58,000**

Evolution of the economic impact and job creation of unconventional hydrocarbon exploitation in France based on Sherpa model simulations from OFCE on the basis of MRP data validated by IFPEN.

Source: Sherpa-OFCE, IFPEN

Even in the pessimistic scenario, the level of job and wealth creation are comparable to high-performing French sectors such as aeronautics (310,000 direct and indirect jobs) or nuclear power (220,00 direct and indirect jobs). It is an opportunity for France to develop a new, excellent industrial sector.

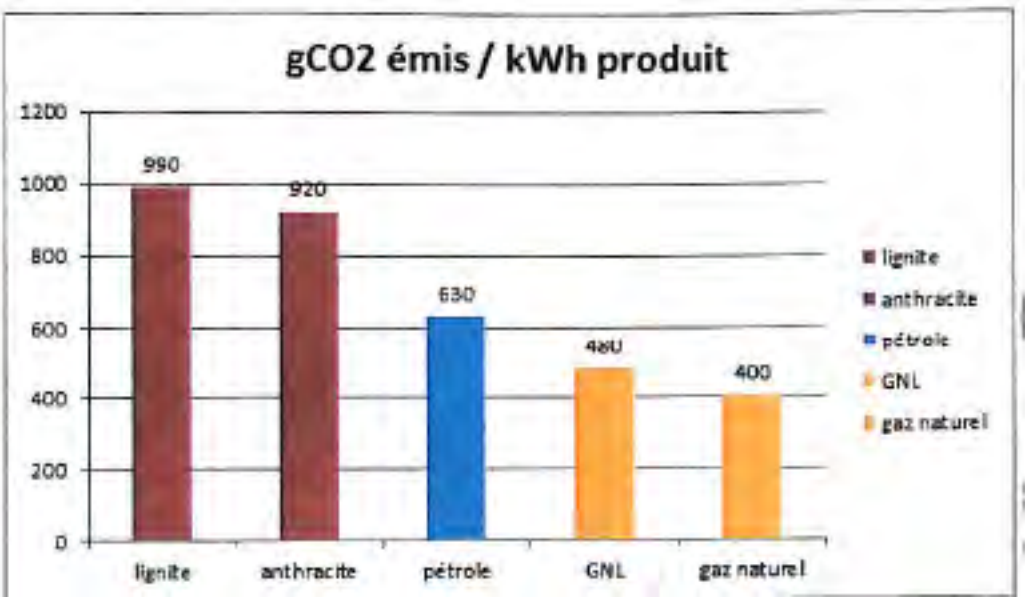
5. AS A SUBSTITUTE FOR IMPORTED GAS, SHALE GAS PRODUCED IN FRANCE CAN MAKE AN IMPORTANT CONTRIBUTION TO THE ENERGY TRANSITION

Shale gas development is in no way in contradiction with an energy transition scenario. It is important to keep in mind that greenhouse gases are a global problem and that emissions are a concern wherever they are produced. Thus, the extraction of energy, the use of energy to transform matter, has the same consequences in terms of greenhouse gas emissions wherever the activity is located. The demand for final processed products and the improvement of production processes are the key variables in greenhouse gas production.

In as much as shale gas in France would essentially lead to a different localization of greenhouse gas-generating activities around the world (corresponding to world demand for a given manufactured product). Therefore, shale hydrocarbon exploitation cannot be assumed to have a negative impact on the energy transition.

5.1. In the United States, the shale gas revolution has contributed to a significant, dramatic reduction of greenhouse gas emissions.

The development of shale gas production in the United States and the lower gas prices that have resulted have shifted power production from coal to gas. For the first time in history, CO2 emissions have fallen in the US, because power plants burning gas emit 2 times less CO2 than coal-powered plants.



CO2 emissions in gCO2 per KWh produced, for each energy used in power production (source: International Energy Agency)

Changes in greenhouse gas emissions in the USA (source: Environmental Protection Agency)

CO2 emissions in the United States have been reduced over the past 5 years, by nearly 400 million tons, returning to 1992 levels. No other country in the world has experienced such a rapid drop – and the United States has not even signed the Kyoto Protocol.

5.2. In France, the issue revolves around replacing gas and oil imports

The French energy mix contributes less to greenhouse gases than the American mix (in particular because of the share of nuclear in power generation). The production of unconventional hydrocarbons in France will not have the same results as observed in the United States, in terms of lowering greenhouse emissions.

However, on the world scale, the impact of the substitution of gas for coal in the energy mix is one of the long-term development trends, compatible with global warming controlled at 2 degrees.

Such national production would not necessarily mean in increase in the share of hydrocarbons in the French energy mix. It would take the place of imported gas and oil (with advantages for the balance of trade). There would therefore be no negative effect with regard to greenhouse gases.

5.3. Exploitation of unconventional hydrocarbons in France will contribute to the energy transition, and income generated thereby can be allocated to that purpose.

National shale gas and oil production would generate revenues that could be used to finance the energy transition.

Looking at the economic projections in the preceding section, revenues generated by unconventional hydrocarbon operations could reach between 94.5 billion euros over 30 years (pessimistic scenario) and 280 billion euros over 30 years (probably scenario).

If one-third of this revenue is dedicated to financing the energy transition, 1.05 (pessimistic scenario) to 3.11 (probably scenario) billion euros could be made available for the energy transition: energy-smart building renovation, investment in energy efficiency, financing renewable energies.

In comparison, the share of support for renewable energy in the *contribution au service public de l'electricité* (consumer tax) represented 3 billion euros in 2013.

5.4. In France, shale gas operations will not lead to a steep drop in prices, as occurred in the Unites States. Such a drop would indeed be contradictory with the energy transition objective.

Shale gas could have a negative effect on greenhouse gas emissions if there was an increasing national consumption of fossil fuels or if long-term investments in low-carbon solutions for processes and products (progressive ramp up of less polluting energy sources) were put off. Shale operations could be seen as sending a negative signal with regard to the carbon constraint.

These negative effects could be expected if shale gas production in France led to the same type of price drops experienced in the United States.

American mining law, unlike French mining law, encouraged price erosion, as each landowner owns mineral rights and that situation led to sprawling, erratic, poorly controlled production. French mining law, on the contrary, encourages logical, State management of production capacity.

For complete control of production flows and to avoid the price collapse, a state-run company should have a monopoly on exploration and operation.

6. FRANCE MUST UNDERTAKE A RESEARCH AND EXPERIMENTATION PROGRAM UNDER THE AEGIS OF A PUBLIC OPERATOR, USING NEW TECHNOLOGIES FOR EXPLORATION AND OPERATION.

The development of unconventional hydrocarbons in the United States, the so-called "shale gas revolution", literally turned the economy around, contributing to economic recovery and industrial renewal, while reducing greenhouse gases, increasing energy independence and resetting the geopolitical balance of the world.

In all countries where significant shale oil and gas reserves are believed to exist, governments are thinking about the best ways to profit from this new opportunity. In

Europe, Great Britain and Poland are implementing incentive measures to encourage exploration and exploitation of unconventional hydrocarbons.

In France, available geological data show a strong potential for shale oil and gas development, mainly in the Paris Basin and in the Southeast Basin (for gas), which, if confirmed, could generate significant resources for the French economy, with a major impact in terms of job creation. But until research and some exploration has been completed, the true scope of technically recoverable resources remains uncertain.

France has chosen to prohibit hydraulic fracturing and public opinion has been very sensitive to the issue of the high volumes of water and chemical additives used. However, a recent survey[67] indicated that 69% of the French approve the idea of carrying out research to find a way to extract shale gas without damaging the environment.

Today, propane stimulation technology, especially with nonflammable propane, uses no water or chemical additives, and is a genuine alternative that can alleviate the environmental problems associated with hydraulic fracturing.

On the basis of this new technology, a program of research and experimentation could be launched. The objective would be:

- To quantify the scope of technically recoverable resources;
- To confirm, in France, the technical efficiency of pure nonflammable propane stimulation, as tested in North America;
- To confirm the economic model for operation based on this new technology.

In order to guarantee the general interest, and in compliance with French aw dated July 2011, this program of research and experimentation should be launched under the aegis of a public agency.

The political choice to name a public agency, which would carry out exploration and production if the phase of experimental proved positive, and which would hold a monopoly, would enable:

- Control of production rates;

[67] TILDERLCI / OPINIONWAY survey on the "eco-question", 6 February 2014 – see annex

- Facilitation of the collection of revenues generated by production, and allocation of a share of the income to the energy transition;
- Guarantee the implementation of environmentally friendly practices, both underground and on the surface;
- Respond positively to issues of consultation, transparency and taking account of local interests;
- Ensure the independence of analyses and decisions made by private interests in the oil industry.

Concretely, the first phase of a program of research and experimentation would take palce over a period of about 24 months. It would have a minimal surface footprint, consisting of:

- Supplementary studies, to add to available geological data, and in particular new seismic lines;
- Three vertical micro-bores[68] per Basin (4 in the Paris Basin and 4 in the Southeast Basin), followed by stimulation of source rock using pure propane.

This experimental phase calls for an investment of about **75 million euros.**

This experimentation phase must also include all measures necessary for monitoring environmental indicators. All of the stakeholders must work in full transparency, with information on each phase of implementation of the experimentation program.

The geological parameters used for selection the location of drill sites are defined below:

[68] Without horizontal extension

Geological characteristics that serve to identify drilling sites

Paris Basin

The most promising production zone for source rock hydrocarbons in the Paris Basin is to the east of Paris. Indeed, this is where the source rock is thickest and where the maturity of the rock has generated the most oil. This zone is divided into to lobes, one to the northeast and the other to the southeast of Paris. Four pilot wells located in these areas would enable identification of the productivity of each lobe. The three first should be set along the central axis of the northeast lobe, in order to test the variation in productivity for various states of maturity. The fourth should be in the heart of the southern lobe, in order to verify its potential and to test the extrapolation of the results from the first three wells in the northeastern lobe.

Southeastern Basin

Going from West to East, the Southeastern Basin is made up of three reservoirs with different characteristics: (1) the first, westernmost, is on the border of the Ardèche region; it is about fifty kilometers across and has been subject to few significant tectonic events apart from the emergence of the Massif Central, at which time the very mature source rocks shifted to depths that are now closer to the surface; (2) the second corresponds to a central zone, fifty to one hundred kilometers wide, which was modified during the emergence of the Pyrenees, the impact of this mountain building is logically different as one moves from the south to north; lastly, the third zone is farther east. There are two types of source rock in this reservoir, on formed during the Lias and one during the Upper Lias-Jurassic. Drilling four to five pilot wells would make it possible to characterize the three areas in account of two parameters: the age of the source rock and the proximity to the Pyrenees, effects of which are mainly felt in the central area of the reservoir. The two fist pilot wells (Well 1 and Well 2) could thus be drilled in the western zone where the first could test the potential of the Lias source rock on the western edge of the zone and the second, the most centrally located, could test the potential of the Upper Lias-Jurassic source rock. The following two wells would be drilled in the central zone; the third, in the

northern section, would identify the potential of the Upper Lias-Jurassic source rock in an Alpine tectonic environment, while the fourth, farther south, would identify the potential of the same Upper Lias-Jurassic source rock in a Pyrenean tectonic environment. Lastly, a fifth well could be drilled in the eastern zone to test the potential of the Upper Lias in this area.

Looking to the future, if the experimental and exploration phase is successful, if public authorities so decide after a public debate with all of the stakeholders, detailed exploration would then make use of forty drill sites per Basin, in the initial period.

If the results of the first phase are confirmed by detailed exploration, complete exploration / production of each Basin (Paris and Southeast) would lead to about 400 well pads, each of which could support about 40 wells with underground horizontal extensions.

In comparison, there are currently 200 oil-drilling operations in the Paris Basin.

Annexes

Annex 1: IFOP – Le Monde – August 2012

Annex 2: Opinionway-Tilder-LCI – February 2014

Annex 3: CGEIET report – Technical report on extracting source rock hydrocarbons using pure propane stimulation

Annex 4: OFCE study – Macroeconomic evaluation shale gas and oil extraction in France

Annex 5: Roland Berger report – Unconventional hydrocarbons in France: after the decision of the Constitutional Court, what next? – November 2013

Annex 6: ***DIG Trésor*** **study –** Unconventional gas development, the economic stakes – September 2012

Annex 7: DGCIS – French industry's position on source rock hydrocarbons – March 2014