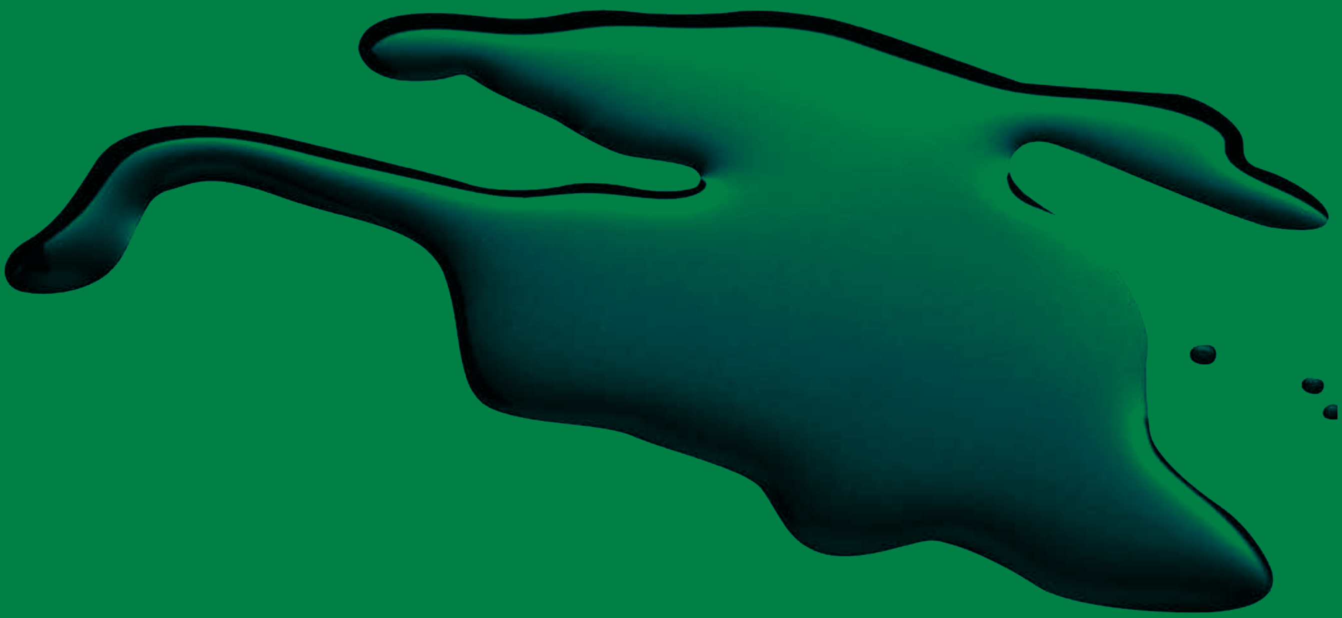
Europe facing peak oil

The Greens | EFA
in the European Parliament



ABSTRACT

Plentiful and cheap oil has enabled Europe to become one of the world's wealthiest modern economies. But today, this has also become Europe's main weak point. Sectors essential to people's way of life have become completely dependent on this non-renewable resource. Millions of Europeans work in industries to manufacture aircraft, cars, plastics and all kinds of appliances that only exist thanks to oil. Millions more nourish themselves on fruits, vegetables and other agricultural products which are grown with fertilisers and biocides derived from the petrochemical industry, and which are transported mainly by road. Millions of people require medicines whose composition includes petrochemical products, go to work every day by car, or warm their homes with heating-oil boilers. Soon the European Union will be importing its entire requirement of this form of energy and, unless it radically reorganises and converts many sectors of its economy, it will be completely subjected to the new constraints that govern the global energy market since the beginning of the century.

We have in fact reached "peak oil" – the maximum level of global oil production that geophysicist Marion King Hubbert modelled in the late 1950s. In the latest issues of World Energy Outlook, the International Energy Agency recognises that the production of conventional crude oil levelled out towards 2006 and has begun to decline. This means trouble, given that the decline will happen at a quicker pace than the development of non-conventional hydrocarbons. Until recently, the two key factors determining production capacity were the price of crude oil and the level of consumption. Today, other constraints have become too strong and too numerous to be ignored. The massive investments required, extreme operating conditions, an increasingly low Energy Return on Energy Invested (ERoEI), significant environmental risks and impacts, and serious geopolitical instabilities are a number of limiting factors that might well preclude the higher production levels forecast by many public and private organisations.

Evaluations of global oil reserves are inevitably inaccurate owing to the large number of operators involved, the confidentiality of certain data, the complexity of the evaluation methods used, and the

vagueness of international definitions. With so many variables, it is easy for oil-producing countries and private oil companies alike to juggle the figures and paint a conveniently vague and misleading picture of the situation in order to further their own aims. It is also possible to give the impression that new oil fields are being discovered every day, when in actual fact the rate of discovery has been falling steadily for over forty years. Since the 1980s, the world has been consuming more oil than it discovers, which means that the oil industry has been using up its stocks. The recent increase in global reserves has been achieved by including long-known reserves of extra-heavy oils from Canada (tar sands) and Venezuela in the estimates. More than 330 billion barrels have thus been added to proven reserves since 1999, although these are not new discoveries and despite the fact that, technically speaking, this type of hydrocarbons cannot be classified as conventional crude oil. Moreover, almost all of the new discoveries that have been made in recent times are located in deep-sea regions requiring very high production and investment costs and entailing much more serious environmental risks.

Everywhere in the world, the best oil fields have been fully exploited, with the exception of Iraq, where the development of the oil industry is hindered by political instability. With a margin of accuracy of approximately 20%, we can say that remaining oil reserves (2P) can be estimated at 1,000 Gb, to which 500 Gb of extra-heavy oil may be added.

Industrial societies are today confronted with the challenge of production capacity – a key factor which in the past made it possible to regulate the price of oil. Historically, global production capacity was managed by the United States up until 1971, when U.S. oil producers had to face the facts: the country was no longer able to increase national production, which had now passed its peak. The OPEC countries took over the task of managing production capacity, which included holding meetings to fix the selling price of oil. However, full international awareness of the vulnerability of oil-importing countries only came with the first two oil shocks (in 1973 and 1979), which can be described as "supply-side shocks". It was at this time that the International Energy Agency was set up and strategic stocks were created in OECD countries. From 2004 to the 2008 oil shock, global production remained surprisingly stable, in spite of a threefold increase in the price of oil.

This shows two things: In the first place, the current oil shock is not associated with a fall in production, unlike the two previous shocks; and, secondly, oil producers have been unable to increase production to halt the upward spiral of prices. The current shock can therefore be described as a "demand-side shock".

Note: This study as well as the reports attached to it as annexes can be downloaded from http://www.peakoil-europaction.eu/

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1. Primary energy is a form of energy found in nature before being subject to processing of any kind. After processing and transport, the energy consumed by the user is termed “final energy”.

2 http://www.gdfsuez-flash-energie.fr/La-facture-energetique-de-l-Europe

I. INTRODUCTION

A. BACKGROUND

After the Second World War, crude oil consumption rose dramatically on a global scale. Further industrialisation and strong demographic pressure generated additional demand for petroleum products. Today the global population consumes in a single day as much crude oil and petroleum products as it did in a year one century ago. The multiple advantages of oil have made it indispensable to the functioning of the global economy. Transport, pharmaceuticals, agriculture, textiles, plastics, hygiene products, heating, road asphalt, metalworking – all the essential sectors of our civilisation have developed on the basis of the availability and low cost of this unique raw material.

In 2011, petroleum products accounted for 38% of primary energy[1] consumption in the EU-27, with approximately 80% being used for transport (62%) and the petrochemical industry (18%). In one form or another, oil is everywhere; it is an essential material for the functioning of modern societies.

At a time when the European Union is facing serious economic difficulties, the price of energy is increasingly adding to Member States’ financial burden. In the period from 2000 to 2010[2], the EU spent on average 1.7% of GDP on oil imports. The situation is now changing, given that the oil bill for 2012 is expected to rise to 2.8% of GDP or more than $500 billion. In spite of the strategic importance of oil for the Union and most countries around the world, great confusion prevails as to the future of global production, with a plethora of expert debates, articles and other publications, and often conflicting and confusing official estimates.

It has become essential today to analyse the situation independently in order to be able to base our decisions on realistic information. By analysing the many events that have marked hydrocarbon-based industrial development over more than one century, and by evaluating – in a scientific, non-ideological fashion – the future energy situation, we should be able to anticipate the consequences of the decline in global oil production for the organisation of the European Union, and thus be able to make informed decisions.

What is commonly referred to as the 2008 financial crisis came in the wake of a major oil shock which, however, was different from previous events of this kind, both in terms of its origins and in terms of its consequences. However, while everyone remembers the economic crash, few link it to the record oil prices seen in 2008. This is why an analysis of this event is essential to understand that the world economy has entered a new phase and that failure to take this into account could have dramatic repercussions.

1. See Section II,C

Even today, economic criteria are regarded by many as the sole constraints on the development of modern societies. Nevertheless, oil is a quantitatively limited resource, and the oil industry faces unprecedented geological, technological and environmental challenges. We now know that every passing day is bringing us closer to inescapable physical limitations such as ERoEI[1] (Energy Return on Energy Invested).

Lastly, the ever increasing complexity of the technologies we use, as well as of the interdependencies between different sectors, makes it very difficult to analyse and fully understand the situation, given the large number of constraints facing us now and in the future, and this can result in inadequate knowledge of the challenges ahead, despite the development of the Internet and increased access to information.

B. STRUCTURE AND SCOPE OF THIS STUDY

This study aims to provide the reader – as clearly and comprehensively as possible – with a picture of the oil situation, including the consequences of various developments and the vulnerabilities affecting the European Union and its population as a result of diminishing oil reserves and higher oil prices. The following diagram shows the principles on which this study is based and its underlying logic.

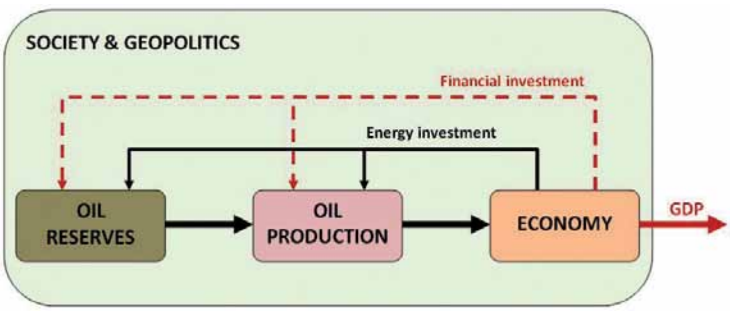

Figure 1: Structural diagram of the study

The first part of this study will look at the state of global oil reserves, highlighting certain inconsistencies and subtleties in official statements. It will then examine production capacity and explain the concept of peak oil, which is the main subject of this study. It will then become apparent that the amount of energy required to discover new reserves and produce hydrocarbons (i.e. the "Energy Return on Energy Invested" or ERoEI) is set to grow at an increasingly rapid pace. The ERoEI, though very often neglected, is nevertheless a key concept, since it determines the amount of net energy ultimately available to make society "work".

The second part of this study will analyse the close link that exists between crude oil production and the economy. In the first place, economic growth requires an increase in oil production. Furthermore, oil prospecting and production depend to a large extent on financial investments, which in turn depend on the state of the economy.

The third (and final) part of the study focuses on Europe, evaluating available oil reserves and production, and analysing Europe's dependence on imports. After outlining a picture of the geopolitical situation of the main oil suppliers, this part ends by examining the European Union's vulnerabilities, as illustrated by a 200-dollar-per-barrel scenario.

SCOPE AND LIMITATIONS OF THIS STUDY

Our aim in this study is to show major trends and take a critical look at the official data. However, in view of the inconsistency of the definitions in use, the political and strategic importance of the statements made by oil-producing countries and oil companies, as well as the confidential nature and large number of relevant data, we cannot always make positive assertions and must adopt a cautious approach in our analyses.

The fact that all sectors and all levels of the global economy are dependent on oil makes it particularly difficult to analyse and predict events which are highly complex. Thus, for example, people's reactions, political and strategic choices, climate change and other global environmental factors cannot be predicted with a high degree of certainty.

Note: Detailed data and definitions are available in the report given as Annexe 1, which can be downloaded from http://www.peakoil-europaction.eu/.

II. CRUDE OIL, AN URGENT ISSUE

"As far as unconventional oil is concerned, it is not the size of the oil field that matters, but rather, the size of the tap."

(Jean-Marie Bourdaire, former Director of the IEA)

One common mistake made when addressing the oil issue with unreflective haste is to consider only the quantity of oil that remains in the ground, without taking account of actual production capacity. In other words, people consider the size of the oil field, but not the size of the "tap". But as we shall see in this first part, the fact that hydrocarbons are present in the ground does not necessarily entail that they can be made available in sufficiently large quantities to meet demand.

A. RESOURCES AND RESERVES: ESTIMATING THE SIZE OF GLOBAL RESERVES

1. DEFINITIONS

When we consider the quantities of available hydrocarbons, we must start by drawing a distinction between "resources" and "reserves". Resources are the estimated amounts of hydrocarbons present in the ground and they are far larger than the amounts actually extracted, given that not all resources are technically and economically recoverable.

The resources that can be recovered technically and cost-effectively are, properly speaking, the "reserves". They are assessed in several stages, including a geological study (description of the oil field), a technical study (extractable quantity), an economic study (cost-effectiveness), and the choice of an appropriate communication strategy (quantities to be declared for political and strategic reasons). On this basis, a probabilistic estimate of the reserves can be performed, i.e. they can be rated according to the probability of their existence. We may therefore distinguish between proven or "P90" reserves (recovery probability higher than 90%), probable or "P50" reserves (probability higher than 50%) and possible or "P10" reserves (probability higher than 10%). The sum of the reserves and the quantity of oil that has already been consumed makes up the "ultimate reserves" or "ultimate recovery", i.e. the total number of barrels that will have been extracted when production ceases eventually.

Reserves are officially classified as follows: 1P (proven), 2P (proven + probable) and 3P (proven + probable

1. David Strahan, Oil has peaked, prices to soar – Sadad al-Huseini, consulted on 17/04/2012, URL: http://www.davidstrahan.com/blog/?p=67

+ possible). While it is usually 1P reserves that are declared, the estimated volume of 2P reserves is the figure which comes closest to the amount that will actually be extracted (in most cases).

2. UNRELIABLE, CONFLICTING, FALSE OR MANIPULATED DATA

Many factors conspire to make it difficult to compare and interpret the data correctly: the complexity of defining reserves and determining their cost-effectiveness, the decision whether or not to include different hydrocarbons depending on oil-content ratios, the tendency to overestimate or underestimate reserves, uncertainties associated with technical difficulties or the political situation, etc.

ULTIMATE RESERVES

The average estimate remained stable for some 60 years at about 2,000 gigabarrels (Gb), but increased recently after the American organisations (USGS, Exxon Mobil, EIA) decided to include non-conventional hydrocarbons in the estimate. Currently, the average estimate is between 2,500 and 3,000 Gb, and only five estimates – out of about 100 – give figures above 4,000 Gb. It is important to remember that all estimates include the resources that have already been consumed, i.e. 1,300 Gb. In other words, humanity has already consumed about half of the oil that can actually be extracted.

Figure 2: Schematic classification of reserves

PROVEN RESERVES

As regards proven-reserves, estimates have been significantly increased over the years in spite of the absence of any major new discoveries: +300 Gb starting in 1985, when OPEC production quotas were introduced[1], +130 Gb in 1999, following the inclusion of Canadian tar sands into the proven reserves, and +200 Gb in 2007, following the inclusion of Venezuelan extra-heavy oil. In total, more than 600 Gb were added to the estimates, without however any new field being discovered. In 2012, global proven reserves are estimated at 1,653 Gb, according to BP's latest publication on the subject, in comparison with 1,383 Gb in 2011 – which represents a 20% increase in only one year. On the other hand, according to the Oil & Gas Journal, reserves only increased by 3.6% over the previous year and were estimated at 1,523 Gb as of 1 January 2012.

BP used the following sources: official primary sources, OPEC Secretariat, World Oil, Oil & Gas Journal, and an independent estimate of Russia's and China's reserves, based on public domain information.

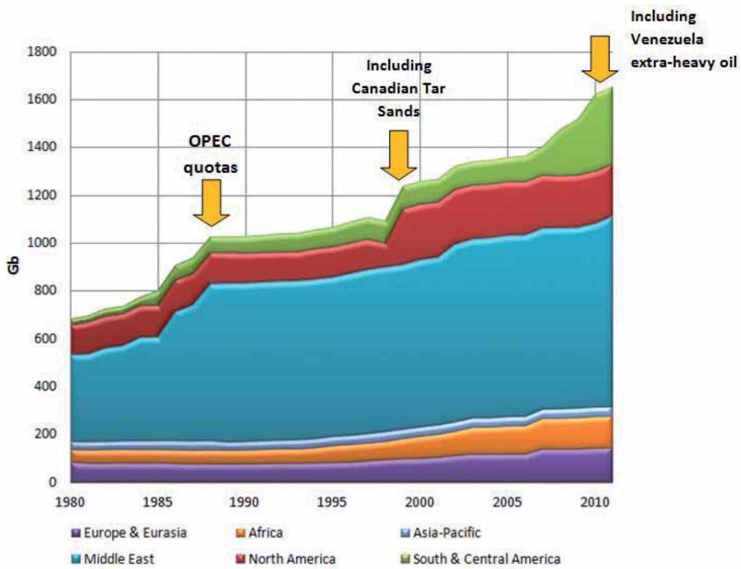

Figure 3: Evolution of global proven reserves 1980-2012 (BP data, 2012)

1. Conversely, adding up 3P reserves leads systematically to overestimation. See Technical Report 1.
2. Backdating the reserves is a method first put forward in 1998 by Jean Laherrère and Colin Campbell in their work "The end of cheap oil", (Campbell & Laherrère, 1998)
3. Accuracy level mentioned by J. Laherrère during a discussion.
4. Jean Laherrère is a petroleum expert and consultant. Having worked for Total for 37 years, he currently provides advice and training around the world on the future of oil exploration and production. He is a founding member of the Association for the Study of Peak Oil and Gas (ASPO).

It should be emphasised that **adding up the proven reserves** (1P) involves a mathematical error which results in underestimating the actual quantities available[1]. Any estimate of global proven reserves that merely adds up the proven reserves of individual countries or world regions is therefore misleading. Underestimation is a practice whereby it is found that the reserves have been growing over the years, which is reassuring for investors.

Overestimating the reserves is also practised, but only by governments, since it can offer them certain political and economic advantages. In the case of private companies this kind of practice is rare because it leads to a loss of confidence among investors and therefore carries significant risks.

Lastly, OPEC countries (which are thought to own three-fourths of world oil reserves) publish an estimate of their reserves each year but, on "state secrecy" grounds, refuse to authorise any independent audit. It is difficult to understand the logic of a country that publishes a set of figures while at the same time considering that these figures are a "secret of state", and we can legitimately ask ourselves **whether such statements are reliable**.

For all the above reasons – and also because official definitions lack accuracy, data are often confidential or unaffordable, and each organisation includes different kinds of hydrocarbons in its figures – the figures declared by various bodies and governments should be treated with **extreme caution**.

3. ESTIMATES CHOSEN FOR THIS STUDY

- Take into account the 2P reserves (proven + probable), i.e. those which more closely approximate the quantities of oil that will actually be extracted;
- Backdate[2] the reserves: A better knowledge of an oil field can lead to a higher estimate of the volumes of oil present. Traditionally, these reviewed quantities are ascribed to the year when the reassessment took place, and this can give the impression that new discoveries have been made. Backdating consists in attributing these quantities to the year when the field was discovered. If we apply this method, it becomes apparent that the remaining reserves resulting from new discoveries have in fact been declining since the 1980s.
- Not take into account – in estimating the amount of crude oil reserves – any reserves of extra-heavy oil (including tar sands), not only for geological reasons but also in view of the fact that development, extraction and processing constraints have become much more stringent.

On this basis, it appears to be more realistic to estimate the remaining crude-oil reserves at **1,000 Gb** (with an accuracy[2] of approximately ±20% to take account of all the estimation uncertainties). For their part, extra-heavy oil reserves are estimated to be in the region of **500 Gb** and are mainly located in Canada and Venezuela. The following graph shows the evolution of these two kinds of estimate. The red curve shows the evolution of 1P reserves, initially underestimating the extractable quantities and subsequently including extra-heavy oil. The green curve shows the evolution of reserves on the basis of the three above-mentioned principles. It is clearly apparent that crude oil reserves resulting from new discoveries have been declining since the 1980s, and that we are consuming more oil than we are discovering.

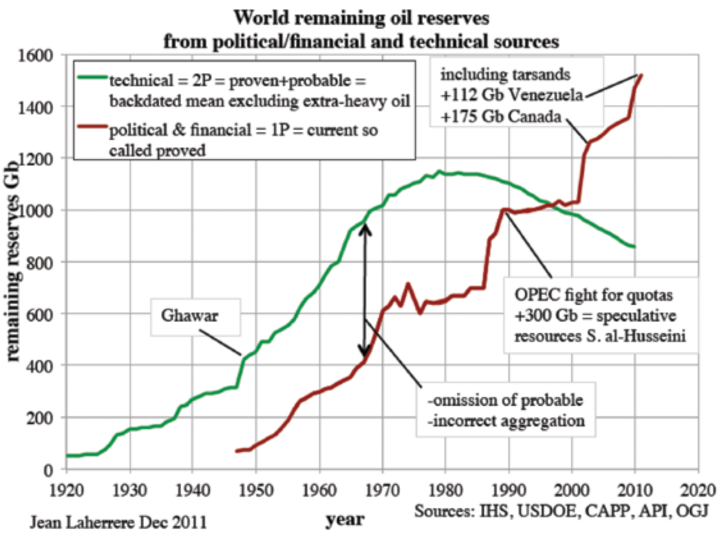

Figure 4: World remaining oil reserves from political/financial and technical sources (Source: Jean Laherrère[4])

B. PRODUCTION CAPACITY OR THE "SIZE OF THE TAP"

Having considered the volume of the remaining reserves, we must now look at production capacity, i.e. the oil industry's capacity to extract, transport, refine and distribute petroleum products to meet demand.

1. PEAK OIL: WHEN THE TAP IS FULLY OPEN

For the sake of simplicity, the media and even some oil industry experts and communicators often express how long oil reserves will last by dividing the remaining reserves by annual production. Thus, we often hear statements to the effect that "At the present consumption rate, we have so many years of oil left." This is the so-called Reserves/Production Ratio or R/P. The graphic representation of such a forecast enables us to realise that it is a purely theoretical construct which does not correspond to any physical reality.

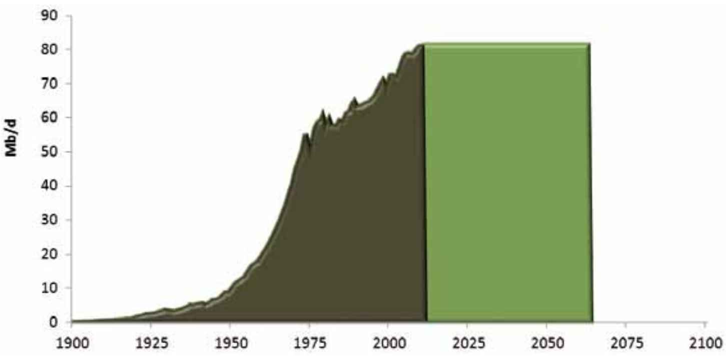

Figure 5: Forecast global oil production, R/P Ratio – 2012 (BP data, 2012)

As apparent from the diagram shown earlier in this study, it is impossible to meet demand on the assumption that it will remain constant over a period of 52 years and then drop to zero overnight. This way of conceiving the future of crude oil production should be discarded since it gives the misleading impression that the situation will remain perfectly stable over a period of many years. But how can we obtain a more realistic forecast of the evolution of global oil production?

In the 1950s, **Marion King Hubbert (1903-1989)**, an engineer and geoscientist with Shell Oil, found that **the evolution of the discovery of oil fields** followed a bell-shaped curve which started at zero, rose to a peak level and then tapered back down to zero. Hubbert then thought that crude oil production might follow a similar pattern and he created a mathematical model (Hubbert curve) into which he fitted the oil data from 48 U.S. States (United States minus Alaska and Hawaii). He thus obtained a bell-shaped production curve that peaks when about half of the oil resources are gone. This "peak oil" value corresponds to the moment when "the taps are fully open". On this basis, Hubbert predicted that U.S. production would begin to decline towards 1970, and history has proven him right.

In 1998, Colin Campbell and Jean Laherrère published a paper that drew worldwide attention: "The End

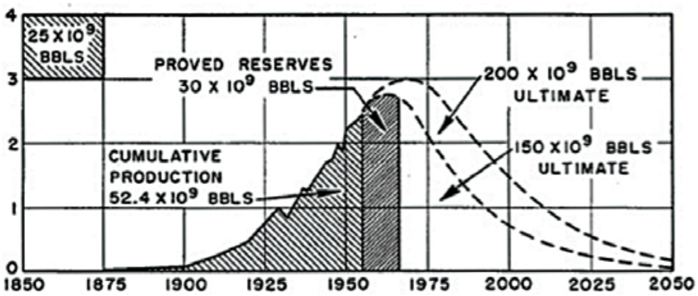

Figure 6: Hubbert curve applied to U.S. crude oil production, based on 150-Gb and 200-Gb ultimate reserves

of Cheap Oil". Its conclusions clearly describe the current situation:

"The world is not running out of oil—at least not yet. What our society does face, and soon, is the end of the abundant and cheap oil on which all industrial nations depend." (Campbell & Laherrère, 1998).

Campbell and Laherrère's study led to increased

1. The term "peak oil" was preferred to "oil peak" because it was thought that the acronym "ASPO" sounded better than "ASOP".

2. The concept of "bumpy plateau" was introduced by Jean Laherrère in 2006. URL: http://www.oilcrisis.com/laherrere/groningen.pdf

international awareness of the concept of production peak. It was followed, in December 2000, by the founding of the ASPO association, which coined the term "peak oil"[1].

Hubbert's work is of major importance, even though the accuracy of his forecasts for U.S. production cannot be reproduced for global oil production as a whole, since a number of additional factors must be taken into account in the latter case. But whatever influence these factors might have in shaping the global production curve, the mathematical area encompassed by the curve must always be the same, given that it represents the quantity of ultimate recoverable resources (URRs).

To illustrate this phenomenon, we may take the IEA reference scenario, which predicts that global production will rise progressively and peak out at 100 Mb/d in 2035. Let us now consider the shape of the curve after 2035, on the basis of the ultimate resources assumed (surface below the curve).

Beginning of decline	2035-2040
Maximum production	100 Mb/d
Required URR	4000 Gb minimum

It is apparent that, if the ultimate recoverable resources (URRs) do not exceed 2,500 Gb (dark green), production will collapse after 2035, dropping from 100 Mb/d to 50 Mb/d. This seems to be an unrealistic and, in any case, undesirable situation, since it means that half of global production would disappear from one day to the next. Similarly, if URRs amount to 3,000-3,500 Gb, we also observe a discontinuity in production, with a sharp decline after the production peak (yellow and orange). Therefore, for the IEA scenario to occur without causing a collapse of global production, the URRs would need to exceed 4,000 Gb (red), which is not the case, according to most estimates.

In addition to estimating the URRs, we must also take account of the **economic factor**. There is a strong correlation between an increase in oil production and economic growth. Oil demand varies depending on the evolution of Gross Domestic Product (GDP): a growing economy requires more oil, and hence the price of oil and investments will tend to grow. Conversely, a recessionary economy requires less oil, leading to lower oil prices and investments. However, since 2005, for technical reasons, price increases have not been enough to push up supply. In this kind of situation, the cost of oil is too high to be absorbed by the economy, which results in lower demand and an economic downturn. These variations then cause a series of ups and downs in production as well as in prices and GDP, giving rise to what is called a "bumpy plateau"[2].

To these constraints we must add the **geopolitical factor**: Certain events can slow down consumption, block oil production or distribution in a country and thus effectively delay global decline. This is what happened after the oil shock in 1973 and as a result of other major events in the following decades.

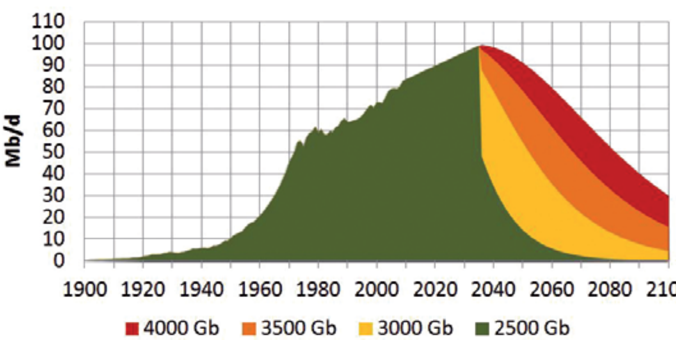

Figure 7: Evolution of global oil production on the basis of the IEA reference scenario and ultimate recoverable resources

1. According to the IEA, there are over 70,000 oil fields, and 95% of the oil lies in the 1,500 largest fields.
2. L. Maugeri has been repeatedly criticised by various experts for basing his study on unfounded or overoptimistic hypotheses.

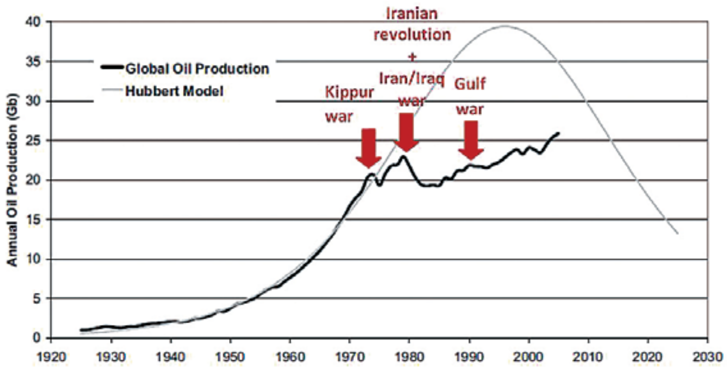

Figure 8: Impact of geopolitical events on global production

2. THE FUTURE OF GLOBAL PRODUCTION

From the Second World War – which marked the beginning of the oil era – up until the period of the oil shocks, consumption increased exponentially. In the early 1970s, OPEC succeeded in regulating supply and demand and imposing its prices. Since 2005, only 33 countries produce more oil than they consume, and therefore all other countries are importers. Although oil prices are high, this is not enough to push up production and meet an ever-increasing demand.

DECLINE IN CURRENT PRODUCTION

The first reason for this is a drop in the amount of oil produced by the oil fields currently in operation. Looking at **conventional oil**, we find that 580 of the largest oil fields[1], which together account for 58% of current global production, have gone into decline. Their production must therefore be replaced by smaller oil fields, which have a higher decline rate. In fact, since the 1950s the average size of newly discovered oil fields has dropped from 400 Mb to the current level of 50 Mb.

Other factors will speed up decline in the coming years. To begin with, the technologies that make it possible to momentarily increase the yield of an oil field (e.g. injection of water or CO2) inevitably speed up the decline rate as soon as the increased production level can no longer be maintained. Furthermore, most new discoveries are made in offshore areas, with higher operating costs leading oil companies to speed up production. In such conditions, both the production rate and the decline rate are significantly higher.

DISCOVERIES AND DEVELOPMENTS IN THE CONVENTIONAL OIL SECTOR

The IEA considers that this decline will be offset by new discoveries and new developments in conventional oil. A recent study by L. Maugeri (which is considered over-optimistic[2]), estimates that it will be possible to produce an additional 14.2Mb/d of conventional oil by 2020. This figure is far above current trends – and far above the figures announced by official organisations – due in particular to the fact that it underestimates the annual decline rate of the oil fields. For example, the IEA estimates – in its central scenario (IEA, 2012) – that Iraq could produce up to 6.1 Mb/d, i.e. a net increase of 3.6 Mb/d in relation to the end of 2011, while Maugeri envisages an increase of 5.1 Mb/d (+40% in comparison with the IEA scenario). We have chosen to apply a reduction coefficient of 15% to 30% (high and low hypotheses) to all the discovery and development forecasts mentioned in this study. This leads us to forecast an increase of the order of **10 to 12 Mb/d by 2020**.

NON-CONVENTIONAL OIL

Firstly, it should be noted that most current discoveries are located in offshore areas, including deep (over 300 metres) and very deep (over 1,500 metres) waters. While there is a significant potential for development, the technical, logistical and financial challenges involved are enormous. The main producing countries for this kind of oil fields are the United States, Brazil, Angola, Nigeria, Norway, Azerbaijan and Egypt. According to the available studies, production from these fields could increase from 3 to 4.9 Mb/d between 2012 and 2020.

1. We have assumed that the decline rate will increase over time and will be higher for offshore fields than for onshore fields. All the details concerning the forecasts are available in the report included as Annex 1.
2. This forecast is the central scenario between the highest and lowest estimates.

There is also production in the **Arctic**, which has attracted much media attention. Apart from any political or environmental considerations, a 2011 study estimates that, under favourable conditions, Alaska's production will start increasing again by 2015, following a period of decline since 1990. Canada's production is set to increase by 2017 (peaking in 2025), and Russia and Greenland's production by 2030. Overall, however, as far as the Arctic is concerned, no **additional production can be expected before 2020** in relation to the current situation. Starting in 2030, we should be able to tap an additional 1.5 Mb/d (Lindholt & Glomsrod, 2011). Furthermore, we should consider the technical challenges posed by this region, including the need for special equipment and systems to ensure the safety of the structures owing to harsh winters and inhospitable terrain, swamping in the hot season, severe working conditions for employees, etc.

Canada's **tar sands** are often mentioned as an example of increased production potential, since these reserves are large and accessible. According to the Canadian Association of Petroleum Producers (CAPP), production could increase from the current level of 1.6 Mb/d to 4.5 Mb/d by 2020, i.e. an increase of **2.9 Mb/d**. However, this oil is mainly imported by the United States, and this tendency is likely to continue, given that 80% of Canadian oil is expected to be supplied to the American market by 2020, which leaves only about 0.9 Mb/d available for the international market. Whatever the future holds in store, the tough operating conditions, the strong environmental impact and the low ERoEI ratio associated with this resource preclude it from becoming the main source of fuel for the industrial economies.

Venezuela has recently been rated as the first most important oil reserve in the world – ahead of Saudi Arabia – thanks to the extra-heavy oil present in the so-called Orinoco Belt. Currently, production from this source does not exceed 0.8 Mb/d and might increase up to 4 Mb/d between 2012 and 2021, according to a Latin American consultancy firm (IPD Latin America, 2012). Taking a much less optimistic view, the IEA estimates that production will reach 1 to 2 Mb/d by 2020. The actual increase will therefore be anywhere between **0.2 and 3.2 Mb/d**.

The United States are now using a new resource, namely **tight oil**. Production has been on the rise since 2008, and a boom in the number of wells over a short period of time has resulted in an unexpected development of this resource. Currently, tight oil production amounts to less than 1 Mb/d, but it might reach 1.2 to 2.2 Mb/d by 2020, according to the IEA's scenarios, i.e. an increase of **0.2 to 1.2 Mb/d**.

The overall production potential for all non-conventional oils in the period to 2020 is somewhere between **6.3 Mb/d to 12.2 Mb/d**.

SYNTHETIC FUELS

The high production costs and significant investments associated with synthetic fuels are likely to limit their development. Global production of biofuels may increase by **0.7-2.7 Mb/d**, according to various estimates, and that of CTL (Coal To Liquid) by approximately **0.3 Mb/d**. As for GTL (Gas To Liquid), the expected increase will be negligible, even if one or two production units are built in the United States. The overall production potential for synthetic fuels in the period to 2020 is of the order of **1 to 3 Mb/d**.

OVERALL PROSPECTS

Having analysed the prospects as regards the decline of existing resources[1] and the production of additional oil and synthetic fuels, we are now in a position to draw an overall picture of the future production of all liquids in the coming period up to 2020. According to the central forecast detailed below[2], production will start declining progressively in 2014-2015.

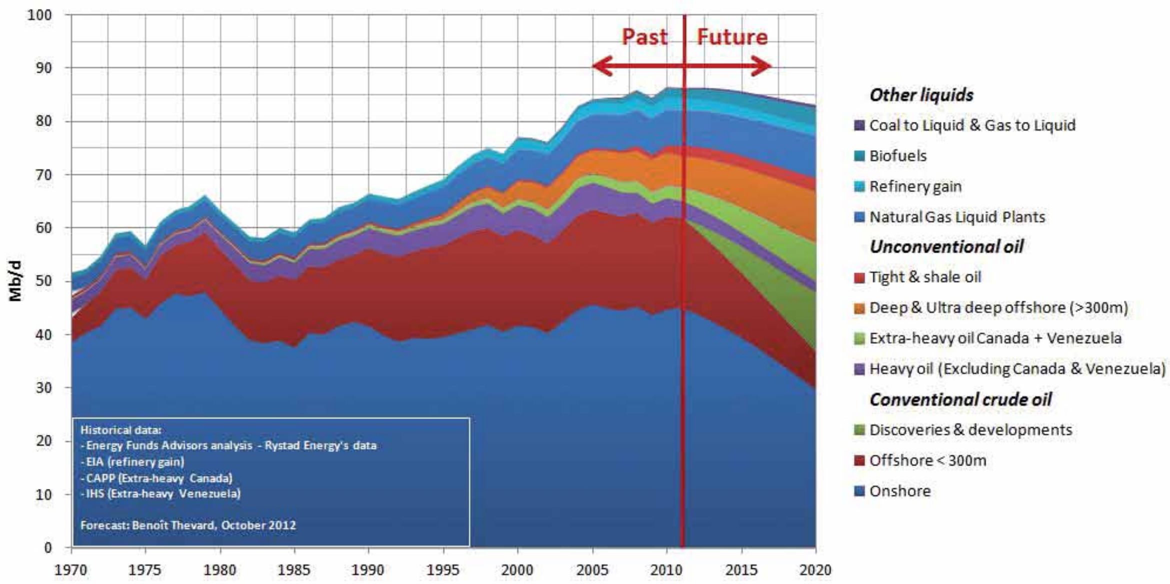

Figure 9: Forecast for 2020: global production of all liquids ("central scenario")

It should be stressed that, when it comes to calculating the net amount of energy actually made available to society (See next chapter), the estimates should be adjusted downwards, given that an increasing proportion of energy is used to produce the hydrocarbons themselves.

C. THE LIMITS IMPOSED BY PHYSICS

"So long as oil is used as a source of energy, when the energy cost of recovering a barrel of oil becomes greater than the energy content of the oil, production will cease no matter what the monetary price may be." (M. King Hubbert)

1. DEFINITION OF THE EROEI RATIO

Very often, commentators address the oil issue from a purely economic perspective. It is fact that, up until now, the hike in oil prices has been the main factor enabling new resources to be tapped. This still applies today in the case of Canada's tar sands and U.S. shale oil, which have become profitable as a result of the major increase in oil prices since the turn of the century.

But the fact remains that there are physical limitations to the commercial exploitation of certain resources. To tap a given source of energy, it is first necessary to invest a certain amount of energy. For example, to make use of solar energy, we must manufacture, install and maintain solar panels or concentrating solar power plants. To make use of wind energy, we must manufacture, install and maintain wind farms, and so on. The same principle applies to petroleum: we must find the oil fields, make sure that they can be productive, manufacture and install all the necessary equipment, and organise production.

The indicator that enables us to compare different types of energy is the ERoEI ratio (Energy Return on Energy Invested), also termed “EROI” (Energy Return On Investment) by some authors.

There is no unit for the ERoEI; it is simply the ratio between the amount of energy recovered at the end of the production process and the energy required for the production process.

$$\text{ERoEI} = \frac{\text{(Recovered energy)}}{\text{(Energy used for production)}}$$

In the case of oil and gas, the calculation of the energy consumed for production usually stops when the oil or gas starts flowing from the wellhead. The stages comprising transport, refining, distribution and use are not taken into account, any more than the environmental impacts are. Consequently, the actual ERoEI is more unfavourable than existing estimates (Hall, Balogh, & Murphy, 2009).

Let us consider, for example, American oil in the 1950s. At the time, it was necessary to invest 1 barrel to recover 25 barrels. It can thus be said that the ERoEI was 25 or 25:1 (twenty-five to one).

NET ENERGY

Net energy is the amount of energy left over for society to use, once the amount of energy employed to produce the energy itself has been deducted. The unit used to measure net energy varies depending on the relevant application (kWh, Tep, barrel, etc.). The amount of net energy can be estimated on the basis of the ERoEI. This is done by subtracting the energy used in the production process from the total amount of energy recovered.

$$\text{Net Energy} = \text{Recovered Energy} - \text{Energy Consumed}$$

To return to the example of American oil in the 1950s: As we have seen, approximately 25 barrels of oil could be recovered per single barrel invested. To achieve a total production of 1 million barrels, it was thus necessary to invest:

$$\frac{1.000.000}{25} = 40.000 \text{ barrels}$$

Therefore, the energy actually made available to society was:

$$\text{Net Energy} = 1.000.000 - 40.000 = 960.000 \text{ barrels}$$

Let us examine now the example of U.S. corn ethanol, whose ERoEI is 1 (between 0.7 and 1.3, according to different studies). To produce 1 million barrels, it is necessary to invest:

$$\frac{1.000.000}{1} = 1.000.000 \text{ barrels}$$

Thus, the net energy available to society is:

$$\text{Net Energy} = 1.000.000 - 1.000.000 = 0 \text{ barrels}$$

Even though there might be economic benefits derived from tax rebates and subsidies, the production of corn ethanol does not – on the face of it – provide society with any additional amount of energy.

1. This graph is an adaptation of the "Net Energy Cliff" graph created by Euan Mearns in 2008.

2. THE MINIMUM EROEI REQUIRED BY ANY SOCIETY

When crude oil first began to be exploited industrially, investing one barrel of oil made it possible to recover 100 barrels, and the ERoEI was therefore 100:1 (one hundred to one). Thus, the net energy available to society amounted to 99 barrels per barrel invested. At the time, the oil wells were shallow, the oil was very liquid and easy to extract, and the energy return on investment was excellent. The technology used was very rudimentary but quite adequate to meet demand. As time went by, the demand for oil increased, and production and prospecting technologies improved. The largest fields of conventional oil were discovered in the 1950s and 60s, enabling a massive increase in production at low financial and energetic cost.

Very soon, however, certain physical limitations – such as pressure loss, the need to drill deeper, higher oil viscosity and increased rock hardness – began to emerge. Technology was developed to overcome these obstacles, but only at the price of an increasingly higher consumption of energy, equipment and materials. For example, after experiencing a fourfold reduction between 1930 and 1950, the average ERoEI of the American oil industry dropped from 24:1 to 11:1 between 1954 and 2007 (Guilford, Hall, O'Connor, & Cleveland, 2011). In other words, twice as much energy is required today in the United States as in 1954 to obtain the same amount of available net energy.

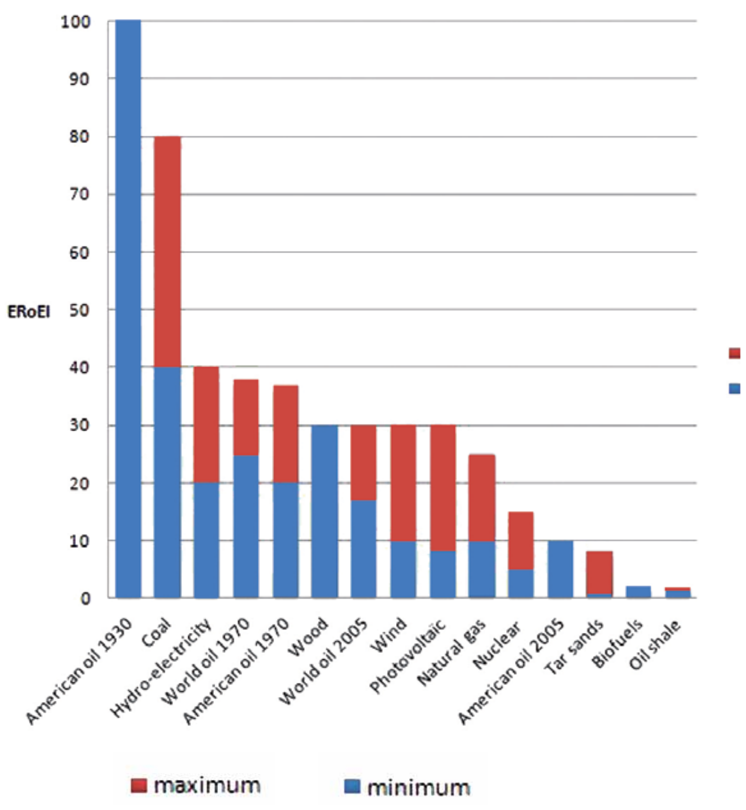

Figure 10: ERoEI by type of energy (adapted from Hall & Day Jr., 2009)

A high ERoEI means that a large amount of net energy is made available to society. In other words, the development of our industrial civilisation over the past decades has been made possible by the availability of a huge quantity of net energy, since only a very small investment of energy was required to recover a large amount of energy. The net energy could then be used by all other industrial sectors (construction, healthcare, agriculture, leisure industry, etc.). The following chart[1] shows the evolution of net energy in relation to the ERoEI and makes it apparent that the amount of available energy drops dramatically when the ERoEI falls below 8-10.

Against the background of the decline of the oil fields currently in production, the situation is currently in a state of flux and many eyes are turning towards non-conventional resources, whose ERoEI, however, is increasingly low (tar sands, extra-heavy oil, biofuels, tight-oil, shale oil and gas). We shall return to this issue later on. Now, there is a minimum ERoEI level below which a society will no longer be able to sustain its economy and essential social functions (Hall, Balogh, & Murphy, 2009). If most or all energy is used to produce energy, little or nothing is left to enable a society to function.

According to Hall, Balogh, & Murphy (2009), the minimum overall ERoEI required for the functioning of a civilisation such as ours is **around 10**.

1. Nates Hagen, “Unconventional oil : tar sands and shale oil, EROI on the web”, The Oildrum, consulted on 30/07/2012, URL: http://www.theoildrum.com/node/3839
2. We are dealing here with energy equivalents since, in reality, other, cheaper types of energy are generally used in the production process. In the case of tar sands, natural gas is often used, and nuclear energy is also being considered for this purpose.
3. The results of this study were criticised in an independent report which suggests an ERoEI of 0.7 (Pimentel & Patzek, 2005)
4. Science Daily, “Oil will run dry 90 years before substitutes roll out, study predicts”, consulted on 07/09/2012, URL: http://www.sciencedaily.com/releases/2010/11/101109095322.htm

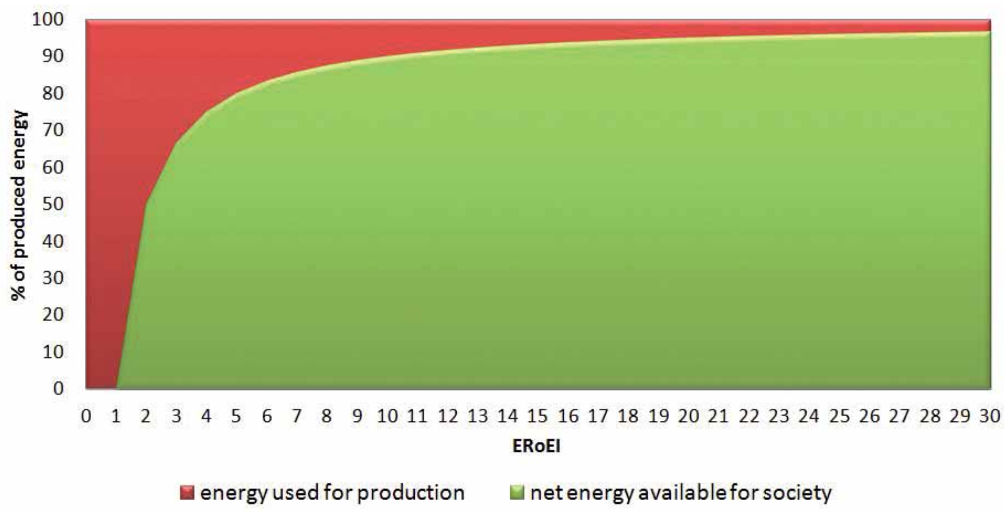

Figure 11: Evolution of net energy in relation to ERoEI

Awareness of this ultimate limit should lead us to question the very sustainability of a society whose functioning would largely be based on energy sources such as tar sands and biofuels. Consider, for example, the fact that the average ERoEI of tar sands is estimated at 5[1]. This means that an amount equivalent to 20% of the energy recovered is consumed in the course of the production process. More specifically, this means that, of the estimated 4.5 Mb/d that Canada will produce by 2020, only 3.6 Mb/d will actually be available to society[2].

Things are even worse in the case of corn ethanol, whose ERoEI is estimated at 1.3[3] by the U.S. Department of Agriculture (USDA). In this particular case, no less than 75% of the energy generated must be reinvested into the production process. If we also take into account the energy subsequently required for transport, distribution and use of this fuel, we actually end up with a negative return on investment, i.e. the production of corn ethanol does not provide society with any additional energy, but, on the contrary, consumes more energy than is made available to society.

D. THE MYTH OF SUBSTITUTION

When it comes to looking for alternative solutions, we should not only ask ourselves whether any suitable technologies exist and whether they work. We must also consider whether these technologies allow us to preserve our current way of life, including mobility in particular. As we have seen, the decline of global oil production will start before 2020.

Apart from technology as such, switching to a new energy model would require carrying out – in the space of a few years – a profound transformation in terms of organisation, equipment and logistics. It would be necessary to build new factories, modify the transport and distribution networks, replace the vehicle fleet, etc. Under the circumstances, we consider that a technology that is still in the experimental stage will not be able to offset, within the available time, the shortfall in energy supply.

INVESTMENTS

A study commissioned by the University of California[4] suggests that, on the basis of investment levels in 2010 and at the current pace of research, it might take

1. Ratio between the kinetic energy of an automobile's wheels (use) and the primary energy used to produce the hydrogen (production). This concept makes it possible to determine the total energy lost when using a particular type of fuel.
2. Eurostat data

up to 90 years to fully replace petroleum as a source of energy. The study, published in the Environmental Science & Technology journal, bases its estimates on a probabilistic approach which takes into account financial market expectations and the overall level of current investment in alternative energy sources. The evaluation does not focus on technology as such, but rather, makes use of financial criteria, including the combined sum of market capitalizations of oil companies and other companies active in the alternative energy sector, the dividends paid to the shareholders of such companies, etc. However, it is not the complete replacement of oil which it is essential to evaluate, but rather, our ability to progressively offset the decline of oil production in all everyday applications.

HYDROGEN

Often presented as the energy of the future, hydrogen is not, properly speaking, a source of energy. This gas is never (or almost never) found in a natural state on Earth. It is therefore necessary to produce it. There are three ways of doing this: water electrolysis (which requires electricity and water), the reforming of hydrocarbons (mainly natural gas) and the thermochemical splitting of water (requiring temperatures above 1,000°C and hence a large amount of energy). Currently, 95% of the hydrogen consumed worldwide is produced from natural gas, which is a non-renewable fossil resource. The large-scale production of hydrogen by electrolysis would require a huge increase in the production of electricity, and the latter is mainly produced by burning coal, which is also a fossil fuel and which, moreover, emits large amounts of carbon dioxide during combustion.

Once hydrogen has been produced, it must be compressed in order to reduce its volume. In the case of motor vehicles, the required pressure is of about 700 bars (300 times the pressure of a car tyre) and the compression process consumes the equivalent of 20% of the energy contained in the hydrogen (Durand, 2009). Of course, the hydrogen must also be stored and transported, which not only generates many losses but also gives rise to many risks. Finally, using hydrogen requires fuel cells, which are too expensive to produce because of the platinum contained in them and whose lifetime is still too short. In summary, there are many barriers to the development of hydrogen as a fuel, not to mention its very poor well-to-wheel efficiency[1] (between 2% and 8.5%, depending on the method used to produce electricity). Hydrogen will be used for specific applications, but it will not replace oil in most current applications, in terms of the costs incurred and within the required timescales.

ELECTRIC POWER

The French Petroleum Institute (IFP) has estimated that increasing the current production of electricity by 20-25% would provide enough power to cater for the needs of a fully electrified fleet of private and business vehicles in France. However, France's nuclear power plants (which account for about 75% of the country's electricity production) are unable to meet current needs during peak power consumption periods, and close to 50% of the nuclear reactors are operating past their initial 30-year lifespan. An overall output increase of 25% seems unrealistic under the circumstances.

EU-wide, the number of petrol- or diesel-fuelled vehicles in circulation comprises 230 million passenger cars, 30 million trucks and 800,000 buses and coaches[2]. These would all have to be replaced, given that, as in the case of hydrogen, they are not designed to be powered by the proposed source of energy.

Other factors will hinder the generalised use of electric vehicles:

- The need to equip all service stations;
- The need to strengthen the power grid to meet the heavy power demands of battery-charging;
- The energy density of an electric battery is 100 to 150 times lower than that of oil (1kg of battery yields 80 Wh versus 11,500 Wh for 1 kg of oil), and

1. Jim Motavalli, "Ultra-green Europe slow to buy electric vehicles", Forbes, consulted on 07/09/2012, URL : http://www.forbes.com/sites/economics/2012/05/04/ultra-green-europe-slow-to-buy-electric-vehicles/

2. Glyphosate is a total (i.e. non-selective) chemical herbicide, used in this case to prevent contamination of the seaweed crop by other plants.

this will limit the autonomy of electric vehicles in all cases;

- The manufacturing processes, materials, toxicity, lifespan and recycling of batteries continue to pose serious obstacles to the development of this type of energy source.

Electric vehicle sales account for 0.09% of the European motor vehicle market, i.e. some 11,500 electric vehicles in 2011[1]. Electricity is therefore likely to replace oil for certain modes of transport but it will be impossible to move from internal-combustion-powered vehicles to electric vehicles without reducing the size of the fleet (fewer vehicles) as well as the frequency, speed and length of journeys (Cochet, 2005).

The use of electricity to power aircraft will remain confined to the experimental realm for a long time to come, as apparent from the performance results of the most recent and most publicised experience in this area (Solar Impulse): 400 kg of batteries (i.e. one-fourth of the aircraft's total weight) and 200 square metres of solar panels were needed to transport a single person at 70 km/h. At present, there is no credible alternative to fossil fuels for aircraft, if we except biofuels. To meet the total fuel requirements of today's air fleet with jatropha or camelina fuel (the sole cost-effective techniques), it would be necessary to cultivate 2 to 3 million square kilometres, i.e. a surface area 4 to 5 times the size of France. The industry is not aiming to replace all the kerosene used in aviation but only about 50% by 2040, which represents a cultivated area of some 1-1.4 km^2. By way of comparison, the total cultivated area of the United States is estimated at 1.7 million km^2. Seaweed cultivation would require a much smaller surface (35,000 km^2) since it has a much higher yield, but it is still not viable today in terms of production costs. At any rate, seaweed cultivation would require developing:

- Large-scale logistics systems to transport the crop and ensure an adequate supply of fuel to the consuming countries
- Factories to process the raw material into fuel
- Factories to produce fertiliser (up to 35,000 tonnes of nitrogen fertiliser per day) and glyphosate[2] (up to 2.5 million litres per day).

NO EQUIVALENT TO CRUDE OIL

Hydrocarbons offer undeniable advantages and cannot be replaced by alternative energy sources without radically changing current practices. The abundance of crude oil, its low cost and ease of extraction, transport and distribution, as well as its high energy density, are the reasons why, in the space of a few decades, it became the life-blood of the economy. Even though alternative energy sources have a place in present and future applications, they will not be able to replace oil and at the same time allow us to retain the current social model.

E. THE U.S. SHALE GAS BUBBLE

The extraordinary development of shale gas production in the United States (14-fold increase in the past 5 years) is leading other countries that have large reserves of this hydrocarbon to consider embarking on this new kind of energy production in order to reduce their energy bill. However, the American experience provides some good clues about the implications and sustainability of such an energy policy. As a matter of fact, people are already talking about a "shale gas bubble" and we shall now consider why.

1. SOME TECHNICAL BACKGROUND

A key characteristic of shale gas (and shale oil) is that it is locked into the bedrock, which consists mainly of clay and is therefore impermeable. As a result, the gas does not tend to migrate, and is located in deep areas (1,500 to 4,500 metres). To recover the gas, the bedrock must be artificially fractured, and to do this the oil industry uses two different techniques. The first is horizontal drilling, which makes it possible to drill through a thin

1. Northwest Regional Planning Commission, "Frac sand and transportation", consulted on 11/09/2012, URL: http://www.nwrpc.com/DocumentCenter/Home/View/109

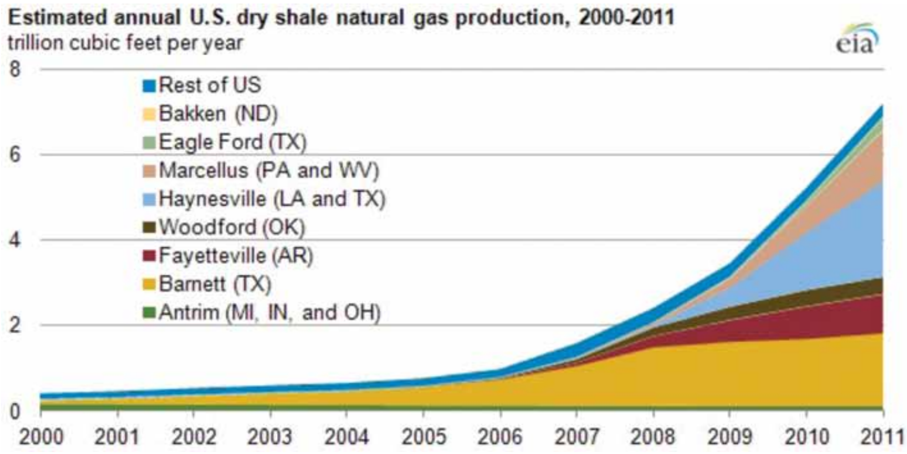

Figure 12: Evolution of shale natural gas production in the USA (Source: EIA)

horizontal seam of shale-gas formations over a distance of several kilometres and limit the number of installations at ground level. The second technique is hydraulic fracturing, which involves injecting large quantities of a mix of water, sand and chemical products (about 1%) at high pressure (600-1000 bars).

In 2012, oil producers were hampered by two mayor constraints. To begin with, water shortages resulting from the record drought that hit the North American continent and, secondly, ensuring an adequate supply of sand, which is injected during the fracturing process in order to keep the fractures open.

WATER MANAGEMENT

This is a major problem associated with shale gas extraction, particularly during periods of drought, as in the United States in the summer of 2012. Each fracturing procedure requires 15,000 to 22,000 m^3 of water, to which 15 to 150 m^3 of chemical products are added (depending on the technique used and the local geological structure). Only a certain proportion of the mix (30 to 50%) returns to the surface owing to pressure. Equipping a 10-km^2 surface area for shale gas extraction involves contaminating close to 400,000 m^3 of freshwater. The water can be treated on site at the well or, alternatively, it can be conveyed to a water treatment facility. The contaminated water, which has been circulated under high pressure through sedimentary layers, has a high content of salts and suspended toxic substances. The initial supply of the water alone requires 1,000 to 1,200 water-truck trips. This is, of course, a problem in terms of local environmental degradation, road maintenance, CO^2 emissions and dependence on oil. Producers are now turning to a range of techniques designed to desalinate and recycle the water from deep oil fields and aquifers in order to avoid competing for freshwater with the agricultural sector.

THE PRODUCTION AND TRANSPORT OF FRAC SAND

Towards the end of September 2012, all the parties involved in the production, logistics and consumption of frac sand were brought together to discuss the major problems faced by the industry. Between 2009 and 2011, sand production increased from 6.5 to 28 million tonnes, and demand is expected to rise by 15% per year in the next three years. The challenges ahead are colossal, as are the infrastructures that need to be built. Close to 100 sand quarries have been opened around the United States over the past two years. The large number of trucks in operation is placing an increased burden on the road system, pushing up the number of accidents and aggravating pollution. Lastly, the investments required to provide adequate rail transport will cost $148bn by 2028 if the objectives are to be achieved[1].

As can be seen, the shale gas boom comes at a very high cost in terms of infrastructure, environmental degradation and various other nuisances. The above also applies to shale oil and tight oil, given that they are extracted by the same type of process.

1. In the region of Haynesville, the total cost of offsetting the decline in production has risen from $8Bn to $13Bn in the space of two years. (Arthur E. Berman, ASPO Conference 2012)
2. Arthur E. Berman is an American geological consultant and a specialist in prospecting and production evaluation, reserve assessment, risk evaluation, and subsurface geological and geophysical interpretation.
3. Chris Nelder, "What the frack?" Consulted on 12/09/2012. URL: http://www.slate.com/articles/health_and_science/future_tense/2011/12/is_there_really_100_years_worth_of_natural_gas_beneath_the_united_states_.html

2. A SHALE GAS BUBBLE?

The boom of shale hydrocarbons is beginning to subside. In addition to the various constraints we have just mentioned, another issue seems to be even more important and problematic: How can national production be stabilised against an increasingly higher decline rate?

Unlike other hydrocarbons, shale oil and gas should be considered unconventional since they must be extracted by means of hydraulic fracturing. With this technique, production levels are highest at the time of fracturing and then usually drop by 70% to 80% during the first year. After four years, production is no greater than 5% to 15% of the initial level. In other words, the decline rate of the wells is extremely high. Due to the proliferation of this kind of well, the decline rate of U.S. gas production has increased from 23% to 32% per year over the last decade. Despite the technical improvements that have been introduced, an increasing number of wells have to be drilled each year, just to compensate for the decline of the wells currently in operation.

One direct consequence of this phenomenon is an exponential growth of the costs[1] required merely to stabilise production, in addition to an increased risk that production will decline rapidly in the event that certain operators cut down on the number of new wells drilled. Now, this might well happen in the coming months, given that, according to Arthur E. Berman[2], the current price of gas is too low to sustain all the costs involved in production, and some operators will be forced to slow down their activities. After modelling the production of thousands of wells in the producing regions, Berman also found that, in reality, the recoverable resources were **half** the size claimed by operators, who had inflated their figures by estimating a much higher recovery rate than the recovery rates actually observed in the field. The average lifetime of a well in Barnett (Texas) is 12 years, rather than 50 years as claimed – once again, misleadingly – by operators[3]. For all these reasons, the fear of another bubble – driven by exaggerated claims for all the parameters concerned and an underestimation of the industry's overall limitations – seems to be gathering momentum.

The prospect of one hundred years of gas power entails major structural changes, including converting vehicles to gas operation, re-equipping service stations, replacing boilers, etc. This situation poses a very serious risk for the United States, given that, if the shale oil and gas boom does turn out to be a bubble, production will decline rapidly, gas prices will rocket, and substantial investments – mainly financed through debt – will have been made to adapt to an energy source that will no longer be available. The dream of energy independence – which will probably not come true – could lead Americans into a dead end that might prove to be an even worse situation than the one they face today.

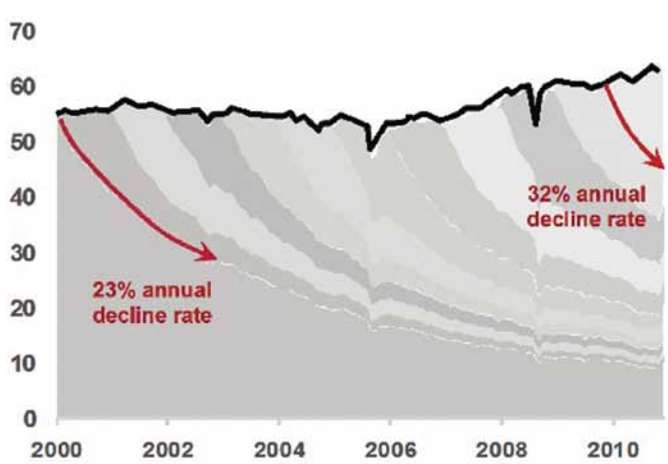

Figure 13: Decline rate of natural gas production in the USA – Y-axis in Bcf/d (Source: ARC Financial Research)

III. OIL, A PILLAR OF THE ECONOMY

A. A BRIEF HISTORY OF CRUDE OIL PRICES

To understand the logic of the pricing of oil today, it is necessary to review the history of the balance of forces underlying price regulation. Reacting to the laws of supply and demand, oil prices have varied considerably over time. From the end of the 19th century to present times, the average price of oil (in 2011 constant dollars) was about $30.9/barrel, but in more recent times (1970-2011) this average price has increased steeply to 48/barrel, which points at a major change in the dynamics of price regulation.

Up until the 1970s, the average price of oil remained fairly stable. The United States, which alone accounted for one-fourth of world production, controlled and fixed the price through the Texas Railroad Commission (TRC), which regulated production. In 1971, however, having ascertained that U.S. production was past its peak, the TRC opened the floodgates, abolishing production quotas and thus marking the end of U.S. regulation.

OPEC, set up in 1960 to bring together the main oil-exporting countries, became the main regulator of oil prices, which it fixed on a half-yearly basis. Two years later, the Arab countries' embargo on oil shipments to the United States and other Western countries – imposed in retaliation for American support for Israel during the Yom Kippur War – caused the 1973 oil shock. The price of oil suddenly increased fourfold, from $3 to $12 a barrel. The world had barely recovered from this major shock when the Iranian Revolution in 1979 and Iran's subsequent invasion by Iraq led to another fall in production. This was the second oil shock, with the price of a barrel rising to more than $35.

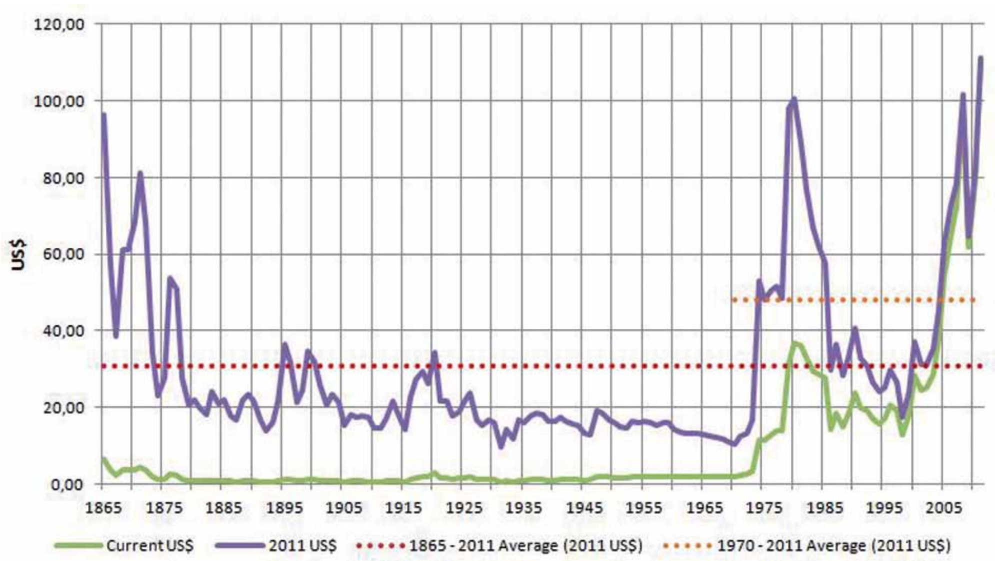

Figure 14: Price of a barrel of crude oil 1865-2011

These sharp increases in oil prices were a windfall for multinational oil companies, which saw their revenues rise and were thus able to engage in the prospecting and development of new oil fields. The resulting rise in production, combined with lower consumption following the oil shocks and an inflationary period, pushed down the barrel price. This was the "oil counter-shock" of the 1980s. OPEC then established quotas to reduce production and push prices up. Managing the situation in this period was a complex business. Saudi Arabia acted as the main regulator, but in 1986, when it decided to forego this role and increase its own production, prices fell again, down to $10 a barrel. The USSR, whose revenues were largely dependent on the sale of oil, was badly hit by this drop in oil prices, which speeded up its downfall a few years later.

From 1988 onwards, OPEC no longer fixed the price of oil directly. Following the progressive liberalisation of the economy and large-scale privatisation of national oil-producing companies, the price of oil was determined by the markets, even though OPEC retained its exclusive ability to regulate the supply of oil by adjusting production levels.

At the end of the 1990s, OPEC unwisely increased production quotas by 10%, at a time when Asia was facing a financial crisis which entailed a steep fall in consumption. This combination of factors led to the barrel price falling to its lowest level since 1971. OPEC then reduced production by approximately 3 Mb/d, enabling the price to rise $25/barrel. Despite the difficulties experienced in anticipating and reacting to events, and although it no longer fixed prices directly, OPEC could still use its control over production levels as a physical lever to react to oil price variations.

The first decade of this century saw an end to OPEC's role as a regulator and marked the beginning of a period of soaring oil prices. In this period, a number of factors conspired to disrupt global production: general strike in Venezuela, decline in production in the United Kingdom and Norway, and interruption of production in Iraq due to the U.S. offensive.

To offset these multiple falls in production, OPEC mobilised almost all of its surplus production capacity, thus leaving a very small safety margin. Tension began to be felt in the markets, particularly since these developments coincided with an increase in U.S. demand (supplies for the armed forces, economic growth) as well as in Asian demand. In 2005, when hurricane Katrina brought about a fall in U.S. production in the Gulf of Mexico and the closure of several refineries, the barrel price rose above $60 for the first time and the International Energy Agency released strategic oil stocks for a period of 30 days.

B. THE 2008 OIL SHOCK

Unlike previous oil shocks, the sharp fall in prices between January 2007 and July 2008 was not due to a significant drop in production, given that global and OPEC production had been stable since 2004. But in the wake of 2005 and the alarming decrease in surplus capacity, OPEC did not increase production to stem the price spiral, even though since the 1970s it had played a unique role in regulating the barrel price.

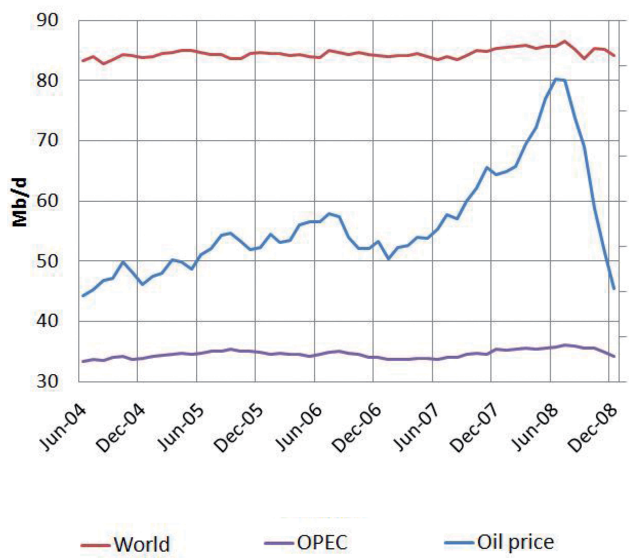

Figure 15: Overall production of liquids (world and OPEC) and barrel price 2004-2008

1. In the space of 25 years, China and India's combined demand has increased almost fivefold, from 2.7 to 13 Mb/d (BP, 2012).

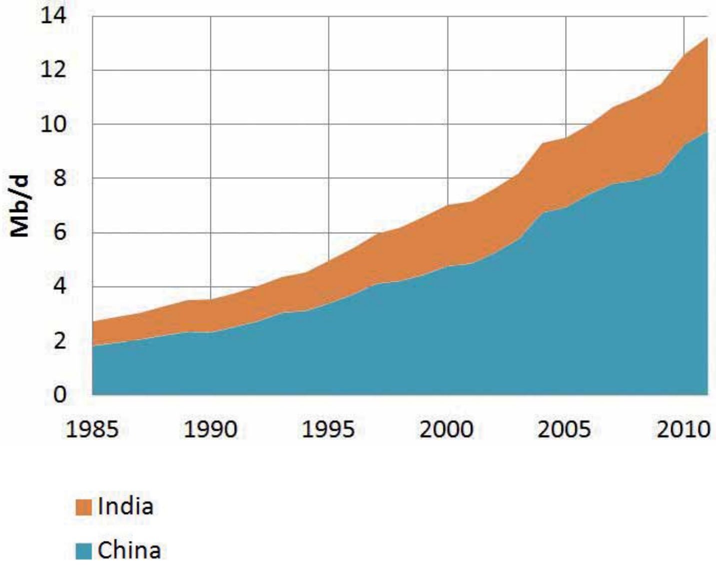

Figure 16: Increase in China's and India's demand for oil (Source: BP 2012)

Stability of supply levels was therefore not enough to meet global demand, which increased by 3% from 2005 to 2007, mainly driven by economic growth in India and China, whose combined consumption rose by 1 Mb/d in two years (+12%)[1].

Inevitably, when supply is stagnant and demand increases, there is a physical unavailability problem. Therefore, a sharp increase in demand from certain countries implies, at constant supply, pushing down consumption in other countries. According to James D. Hamilton, an energy economist, one way of persuading the latter to reduce consumption in spite of their increasing requirements, is a rise in oil prices (Hamilton, 2009, p. 229).

Many studies have contributed to the analysis of the oil shock and bring out a number of determining factors, whose relative importance is still the subject of much debate but whose existence and impact are generally accepted as facts.

1. Peaking-out of global oil production and fall in surplus capacity;
2. Boom in global demand, driven by growth in non-OECD countries;
3. Scarcity rent;
4. Increased speculation in the raw materials markets;
5. Low price elasticity of demand.

We have already touched upon the production and demand issues and will now turn to the other three factors.

1. SCARCITY RENT

When a resource only exists in limited quantities, its owner can manage it in one of two ways. He may decide to market it immediately. In such a case, the selling price must incorporate production costs as well as what is termed the "scarcity rent" (or "Hotelling's rule"), which takes account of the fact that the resource will not be renewed and will necessarily become more expensive in future. The owner of the resource can invest his profits and earn interest on them. But the owner may also anticipate that the resource will become more valuable and that he will make a larger profit by selling it tomorrow than by investing the profits made today. He may therefore decide to keep the resource in order to sell it at some point in the future.

In actual fact, the concept of scarcity did not basically apply to oil at the beginning of the 20th century, and for a long time thereafter, since more oil was discovered than was consumed. Overall, the selling price matched production costs and therefore there were no price increases resulting from the scarcity rent, as described by H. Hotelling in the 1930s. It was only in the 1970s – against the background of the peaking out of U.S. oil production and the oil shocks – that the concept re-emerged as a result of increased awareness of the limited availability of the resource.

More recently, technological progress has enabled us to access resources which were previously considered unrecoverable. We now know that there are vast

1. New York Mercantile Exchange (NYMEX) and Intercontinental Exchange (ICE)
2. NYMEX was taken over by the group CME (Chicago Mercantile Exchange) in 2007.

amounts of oil underground, but a large proportion of that oil will remain untapped. At present, technological and political constraints, a low ERoEI and production costs are the main factors limiting the recoverability of the resource. Hotelling's rule, in its simplest form, basically applies to existing stocks of the resource and is therefore not enough to explain the sharp increase in oil prices in recent times.

However, certain producing countries may well choose to keep their resources for later. A striking illustration of this was provided in 2008 by the Reuters News Service, which reported that the King of Saudi Arabia had ordered the new discoveries to be left untouched for the benefit of future generations (Hamilton, 2008).

The scarcity rent is something very real and it is undoubtedly factored into the price of oil.

2. SPECULATION

At present, most oil trading takes place on stock exchanges (Union Pétrolière, 2005) through two organisations, namely NYMEX an ICE[1], based in New York[2] and Atlanta respectively.

The exchanges take the form of hedging or speculative operations, on the basis of more or less subjective forecasts of the geopolitical context (risk of conflicts, etc.), the economic context (growth or recession, etc.), the energy context (level of existing stocks, etc.) and even the meteorological context (harshness of the winter, presence of hurricanes, etc.). Psychological factors can therefore strongly influence price trends.

Hedging is mainly practised by producers and consumers (refiners, airlines, etc.) who wish to minimise the risks associated with possible sharp price fluctuations when buying or selling oil. In this case, the aim is to limit the risks incurred (Union Pétrolière, 2005).

Speculation is not practised by actual producers or consumers, but rather, operators aiming to make a profit by gambling on market trends. Contrary to hedging, speculation involves taking risks. Usually practised by non-specialists in the oil industry (who are unfamiliar with the physical constraints faced by the latter), speculation increases volatility and the amplitude of price variations.

In 2000, U.S. President Bill Clinton signed the Commodity Future Modernization Act (CFMA), by which certain oil derivative markets were removed from the jurisdiction of the Commodity Futures Trading Commission (CFTC) and therefore withdrawn from its control. This easing of regulation and the prospect of higher oil prices caused a radical change in the structure of the market.

In the first place, there was a huge increase in the number of futures contracts, reflecting the interest shown in the market by many sellers and buyers. As apparent from Figure 17, the number of futures contracts for oil more than tripled between 2005 and 2008.

Secondly, the profile of market operators changed over the same period. In fact, there are three main types of market operators:

- Commercial operators: producers, refiners, distributors, major consumers
- Non-commercial operators: traders, hedge funds and non-registered participants
- Operators/agents performing swaps of raw materials

Figure 17: Evolution of number of open futures positions and the price of a barrel from 1995 to 2012 (Williams, 2011)

1. The difference between the spot price and the future price of oil is determined by the dynamics of speculative stockpiling; that is to say, the future price is equal to the spot price plus storage costs, plus the applicable interest rate, minus the "convenience yield" (convenience of a readily available stock of oil).

Non-commercial operators aim primarily for profit, while commercial operators use futures contracts to limit the risks associated with future price fluctuations. From 2000 to 2008, however, the open futures positions held by the latter increased by 63% while those held by non-commercial operators increased by no less than 600% (Chevallier, 2010).

We may also ask what role speculative stockpiling[1] has played in the price increase, but it should be noted that overall storage capacity is limited and that OECD oil stocks fell from 2006 to 2008, which, according to the French Conseil d'Analyse Economique (Council for Economic Analysis), "makes it difficult, in principle, to regard speculation as the main cause of oil price increase in the 2000s" (Artus, d'Autume, Chalmin, & Chevalier, 2010).

3. LOW PRICE ELASTICITY OF DEMAND

The price elasticity of demand (eD) is the ratio of demand for a commodity to a change in price. This concept makes it possible to determine, for a given good or service, the degree to which consumers respond to price changes.

$$e_D = \frac{\%\text{ change in demand}}{\%\text{ change in price}}$$

The price elasticity of essential goods tends to be low, and this also applies to oil. In other words, a large change in price has a small impact on demand. For example, short-term price elasticity (Table 1) for OECD countries is -0.025, which means that a 10% increase in the price of oil will only lower demand by 0.25%.

	Short-term elasticity	Long-term elasticity
OECD	-0,025	-0,093
Non-OECD	-0,007	-0,035
World	-0,019	-0,072

Table 1: Price elasticity of demand for oil (IMF, 2011)

In a context where strong demand coincided with stagnant supply, the low price elasticity of oil prevented consumption from falling to a sufficiently low level to ease the market situation and stem the price rise. Low price elasticity is therefore an important contributing factor to the oil shock.

In view of the above, citizens and policymakers alike should be alerted to the fact that oil has become a basic commodity, essential to the functioning of modern societies, while available reserves of oil are limited and, to date, there is no viable replacement for it.

C. OIL AND THE SUBPRIME CRISIS

The subprime crisis in 2008 impacted the whole world by triggering an economic crisis. For most citizens, however, there is no direct link between this crisis and the oil shock, even though the two events took place in the same period. In the following sections, we will examine the chronology of events in order to highlight that these two developments cannot be separated from each other.

1. From 2002 to 2006, the oil-exporting countries' share of global capital outflows rose from 21 to 37% or $484bn out of a total of $1,319bn.
2. Saleh M. Nsouli, Petrodollar Recycling And Global Imbalances, IMF, consulted on 24/07/2012, URL: http://www.imf.org/external/np/speeches/2006/032306a.htm
3. John Williams', Government economic reports: things you've suspected but were afraid to ask, consulted on 11/09/2012, URL: http://www.shadowstats.com/article/consumer_price_index
4. The median wage is the wage at which half the workers in the population under consideration earned more than that amount and half earned less (definition by the French National Institute for Statistics and Economic Studies – INSEE), and the real median wage is the same figure adjusted for inflation.
5. A country's monetary policy consists in determining or influencing the money supply, financial assets, credit policy and, in some cases, exchange rate policy (as in the case of China), with the aim of limiting inflation and promoting growth.

1. HIGH INFLATION RATE IN THE U.S.A

From January 2002 to August 2006, the price of an oil barrel rose from $20 to $73, i.e. an increase of 265% which significantly boosted the revenues (petrodollars) of oil-exporting countries. In 2006, these countries became the largest global source of capital flows[1], a sizeable proportion of which was recycled into U.S. treasury bonds[2]. The Asian Central banks also invested a substantial part of the proceeds of economic growth in treasury bonds. This massive twofold influx of liquid assets resulted in a fall in interest rates, a sharp rise in demand in the real market, particularly in the real estate market (Spencer, Chancel, & Guérin, 2012), and hence a rise in inflation.

At a more direct level, the hike in energy costs increased the production costs of businesses, both in terms of direct energy consumption (depending, to a greater or lesser extent, on the level of energy intensity of the business concerned) and because an increase in consumer prices leads inevitably to a wage review.

Under the combined effect of these factors, the official annual inflation rate in the United States rose from 1% in 2002 to 4.5% in 2006. It should be noted in this connection that, according to John Williams'[3], the method employed for calculating the Consumer Price Index (CPI) was repeatedly modified, leading to an artificial lowering of the inflation rate. Using the CPI calculation method applied in 1990, the U.S. inflation rate in 2006 would have exceeded 7%. This manipulation of the CPI led to cuts in inflation-indexed welfare benefits and aggravated the financial difficulties of low-income households.

2. CONSUMPTION STIMULUS POLICIES

Since the late 1980s, the real median wage[4] (adjusted for inflation) in the USA has remained stagnant while the income gap between mid- and high-income households has increased steadily. In this context – and in order to promote growth through increased household consumption – greater recourse was made to monetary policy[5] and mortgage loans than to pay rises, thus fostering indebtedness.

However, in order to expand the mortgage market, mortgages had to become more readily available, and thus the subprime credit industry was launched in 2004, especially in the USA and the UK. Subprime loans are loans granted to borrowers with a low credit score and are characterised by higher interest rates in order to compensate for higher credit risk.

The context was therefore conducive to the emergence of a real-estate bubble (particularly owing to the very low interest rates in 2003), against the background of widening income inequality, the pumping up of household consumption through debt, a massive influx of foreign capital, recourse to monetary policies, and deregulation of the financial sector (Spencer, Chancel, & Guérin, 2012).

3. THE SUBPRIME BUBBLE BURSTS

The rise in the price of oil was not the sole reason why the subprime bubble developed and eventually burst. Many other complex factors were involved. However, as we shall see, the price of oil played a major and perhaps a decisive role. In the context of a boom of the subprime credit industry, the main risk is payment default, given that the loans are granted to borrowers with low credit scores, who are usually in low-income social groups.

The oil shock had a direct impact, first and foremost, on borrowers living in suburban areas, who saw their vehicle fuel bills rise from $1,422 to $3,196 per year from 2003 to 2008 (Spencer, Chancel, & Guérin,

1. I.e. the amount of energy required to generate economic wealth.

2. An increase in consumer prices usually leads wage-earners to seek a pay rise. In the United States, however, wage reviews had limited effect and the real median wage remained stable.

2012). Sprawling suburbia make citizens completely dependent on their cars and vulnerable to fuel price increases, which also hinder the development of cost-effective public transport systems. Successive hikes in the retail price of petrol and diesel may well have led to many payment defaults. This direct impact is also very socially unequal since it first affects the families who live furthest away from the city centre and who must allocate a larger part of their budget to energy costs.

Something could have been done to improve the situation when the first oil shocks hit the economy, but the national price controls introduced in the 1970s (see box) had in fact a negative effect, in that they failed to promote the medium- and long-term adaptation of the industry as well as of urban planning policies and people's lifestyles.

THE EXPERIENCE OF NATIONAL PRICE CONTROL

In 1971, President Nixon implemented a price control policy, including the price of oil. The economic impact of the 1973 oil shock on consumers was thereby not as strong as on other national economies, but higher oil price would have probably encouraged oil businesses and the population at large to move towards less oil-dependent technologies and behaviours. This is what happened, for example, in Europe, where the automotive industry developed new vehicle models to limit fuel consumption.

Furthermore, by selling below the global market price, American oil companies reduced their margin of profit and their capacity for investment in prospecting and production.

However, high oil prices are not regarded by all commentators as the decisive factor determining payment defaults, but rather as a contributing factor. For example, in the opinion of the Mortgage Bankers Association" (MBA, 2006), the two most important causes of default are **higher interest rates** and **labour market conditions**, while the price of energy is only a secondary factor. Yet, it was precisely the increase in oil prices that brought about higher interest rates and the stagnation of the real median wage from 2004 to 2007.

In 2004, the U.S. Federal Reserve decided to increase interest rates proportionally to the price of oil (Carr & Beese, 2008). Interest rates thus increased from 1% to 5.25% per year in the space of two years, and this decision had a significant impact on the economy, leading to a drop in the value of real estate and putting many borrowers in difficulty.

Policymakers therefore bear some responsibility for developments, since monetary policy decisions are up to the government. By issuing treasury bonds to raise money, the authorities promoted consumption but also fostered inflation, which they then tried to stem by ruthlessly increasing interest rates. The aim throughout was to maintain economic growth.

As regards the labour market, although the general trends show a correlation between the price of oil, the growth rate and the unemployment rate (Jancovici, 2010), it is difficult to draw any reliable conclusions from this, especially since a country's energy intensity[1] changes over time. Nevertheless, a rise in energy costs increases businesses' production and distribution costs, while at the same time lowering household consumption, which in turn can only result in a slowing-down of the economy and thus in a higher unemployment rate. Generally speaking, higher consumer prices mean that employees will seek to negotiate pay rises, which again increase business costs, thereby fuelling an inflationary spiral. In the United States, inflation was limited only because employers were able to take a hard stance in such negotiations[2] (Peersman & Van Robays, 2009).

On the other hand, wage-earners' purchasing power has dropped dramatically, leading to an increase in the number of defaults.

It is therefore apparent that, whether directly or indirectly, the oil shock has played a major role in:

1/ Inflating the real-estate bubble, given that the massive influx of capital from oil-producing countries brought interest rates down; and

2/ Bursting the subprime real-estate bubble (Spencer, Chancel, & Guérin, 2012) by aggravating the vulnerability and financial difficulties faced by households and increasing the number of defaults.

4. IMPACT OF THE CRISIS ON INVESTMENTS

Although many studies have established a link between the financial crisis and the oil shock, no effective steps have been taken to adapt national economies to the prospect of oil becoming increasingly rare and expensive, in combination with high price volatility. Colossal sums of money are deployed to recapitalise the banks, but relatively few resources are devoted to diminishing industrial civilisation's dependency on fossil fuels.

The recession that followed in the wake of the subprime bubble and the resulting financial earthquake eased the tension on the oil markets by lowering demand, but it also caused a decrease in investments. In 2009, for example, following a sharp fall in the barrel price, investments in the oil industry dropped by 16% in relation to the previous year.

Modern economies have entered a period of permanent instability. The price of oil cannot be stabilised as long as it depends on supply and demand. This is an advantage in relation to the risks incurred when prices were fixed by the OPEC, but a disadvantage in the context of an unstable economy. A growing economy is compatible with low price elasticity, i.e. an increase in demand despite higher oil prices. But as soon as prices rise too high, inflation begins, consumption drops, vulnerable households and businesses find themselves in serious difficulties and the economy falls into recession.

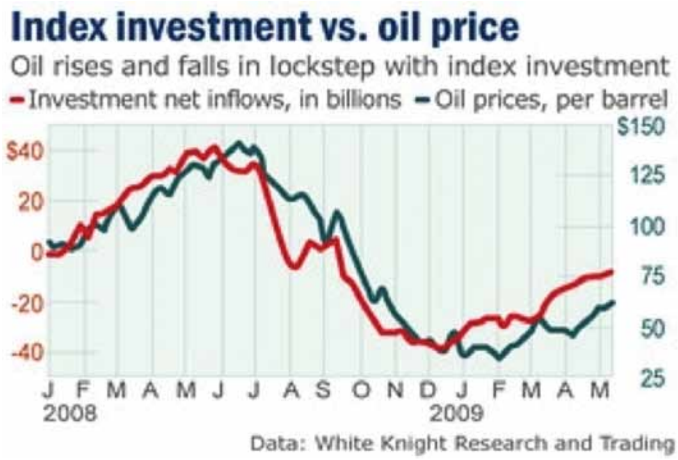

Figure 18: Fall in investments correlated with fall in oil prices (Source: leblogfinance.fr)

Recession automatically brings about a fall in demand, which in turn lowers prices and undermines the cost-effectiveness of many projects. Nevertheless, tackling the growing technical difficulties faced by the oil industry requires increasingly larger investments in order to develop new oil fields under difficult and sometimes even extreme conditions. There is a very real risk that it will prove impossible to implement certain projects due to price volatility.

Note: Detailed data and definitions are available in the report given as Annexe 2, which can be downloaded from http://www.peakoil-europaction.eu/.

IV. RISING TO THE CHALLENGE – WHICH WAY FORWARD FOR THE EU?

A. AN OIL-DEPENDENT EUROPE

Oil is ubiquitous in modern societies. There is hardly a good or a service whose availability is not dependent on the use of oil. Under the circumstances, the impact of a price rise or an interruption of supply will be far from negligible.

The European Union is the second largest consumer of oil in the world, behind the United States. Although consumption is decreasing, oil is still by far the main source of energy in Europe, accounting for 38% of primary energy consumed in 2011 (BP, 2012).

From 1985 to 2000, Europe produced 20 to 25% of its oil requirement. Today it only produces 13%. The net energy bill will thus exceed €500bn in 2012. Oil supply is therefore a key issue for the future of the EU since, even after implementation of the new energy policy, dependence on imports will rise to 92% of the EU's requirement by 2020 (Commission of the European Communities, 2008, p. 18).

In 2010, the breakdown of end consumption by sector in the European Union was as follows (in millions of barrels of oil equivalent).

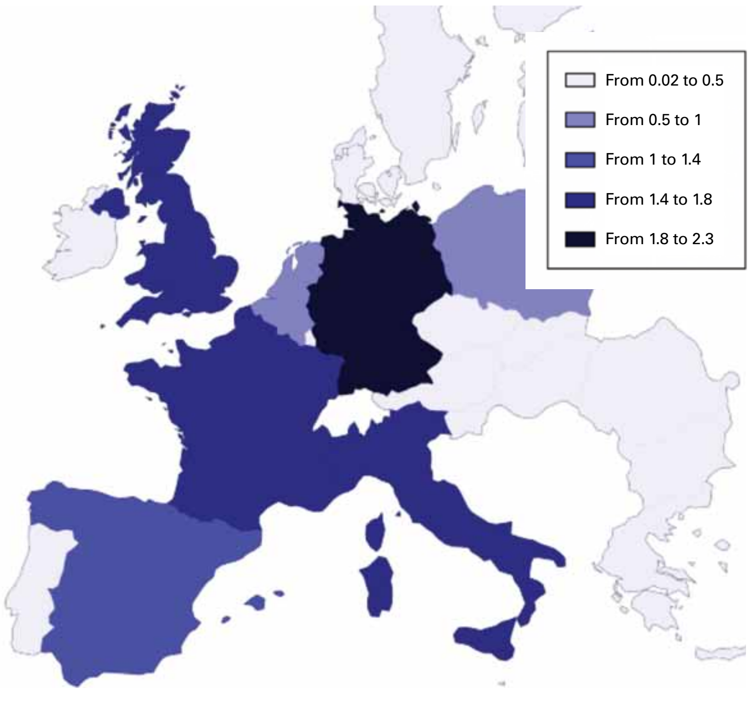

Figure 19: Breakdown of oil consumption in EU27 countries in Mb/d (Source: Eurostat)

Sector	Quantity (Mbpe)	Proportion of consumption
Transport	2510	62 %
Including: Road transport	2080	51,4 %
Air	360	9 %
Sea/Waterways + Rail	40	1,6 %
Non-energy uses	710	17,6 %
Residential	310	7,8 %
Industry (energy)	250	6,3 %
Commerce and services	140	3,6 %
Agriculture, forestry	100	2,4 %
Other	30	0,7 %

Table 2: Breakdown of oil consumption by sector in the EU27 (Eurostat data 2012)

1. The extractive sector comprises all industries exploiting mineral natural resources – whether solid, liquid or gaseous – which are present on the surface of the Earth or underground, including offshore marine areas (INSEE definition).
2. Eurostat data, 2012

If we look at the evolution of consumption in the main sectors, we can observe three distinct trends. Some sectors are increasing their consumption of oil, except during economic downturns, like the one in 2008; other sectors are reducing their consumption of oil but not of energy, which indicates that oil is being replaced by other energy sources; and yet other sectors are reducing their consumption of oil.

- Tendency to higher consumption:

Oil consumption for non-energy uses is on the rise in the industrial sector (+30% from 1993 to 2008). The oil shock caused consumption to fall back temporarily to 2001 levels, but this dip is mainly explained by the economic crisis, and the subsequent rebound of consumption suggests that this is not a long-term trend.

- Tendency to replacement of oil:

In other sectors (excluding transport), the trend is toward lower consumption of oil, particularly as a source of energy in industry as well as in the residential sector. Lower consumption in the industrial sector is due to improved energy efficiency but especially to the evolution of the industrial fabric. Over the past 20 years, the volume of production in the extractive sector[1] has declined by 28%[2] while production by manufacturing industries that consume smaller amounts of fossil energy has increased by 27%. In spite of this, however, total energy consumption by the industrial sector has remained stable at approximately 320 Mtpe/year in the past 20 years, except in 2009. In the residential sector, oil is being increasingly replaced by natural gas (+50% in 20 years). However, the improved energy performance of new boilers and the more stringent thermal regulations introduced for new buildings and for the construction/renovation of housing have not prevented an increase in global energy consumption (+7% in 20 years).

- Tendency to lower consumption:

Consumption in the transport sector increased sharply from 1990 to 2008 (+30%), with a twofold increase in the international aviation sector (+100%). But the latest oil shock has apparently reversed this trend, pushing consumption back to 2001 levels. This seems to be an ongoing trend, suggesting both that EU countries have to some extent adjusted themselves to lastingly high oil prices and that the EU economy has slowed down. Given the unavailability of substitute fuels, the transport sector is the top consumer of oil, with a dependency rate of over 95%.

When we consider consumption, it is essential to take into account energy intensity, that is to say, the amount of energy consumed to generate one unit of GDP. Although, overall, the energy intensity index began to fall in 1990 (Figure 20), this trend appears to have reversed in recent years. Contrary to all forecasts, more energy is required today to produce economic wealth than in 2009. It no longer seems possible to rely on a lasting

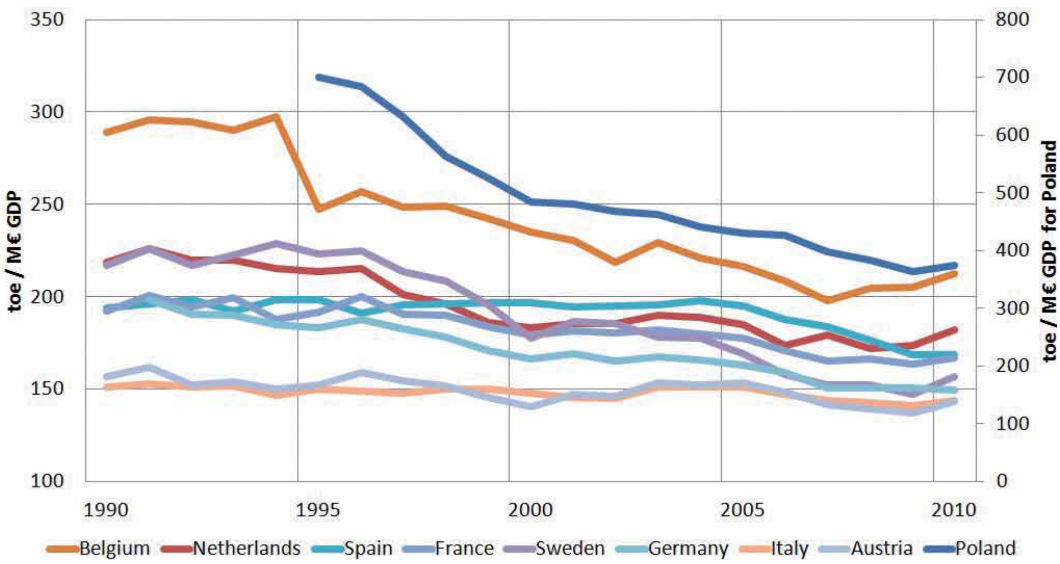

Figure 20: Evolution of energy intensity in the EU's top 9 economies (Source: Eurostat 2012)

reduction of energy intensity when we consider how to improve Europe's energy prospects.

B. AN OIL-LESS EUROPE

While Europe is the world's second largest consumer of oil, its oil reserves only account for 0.4% of proven global resources. This figure is equivalent to Europe's oil requirement over a period of 14 to 16 months, based on the average monthly consumption in 2007. Few European countries produce oil in significant quantities. At present, Europe produces 1.7 Mb/d of conventional oil, with production falling at the rate of 6% per year since 1999.

Proven resources (In Mb)	2011	2012
UK	2858	2827
Denmark	812	900
Romania	600	600
Italy	476	523
Netherlands	310	287
Germany	276	276
Poland	96	155
Spain	150	150
France	92	90
Austria	50	50
Hungary	27	32
Bulgaria	15	15
Czech Republic	15	15
Lithuania	12	12
Greece	10	10
Slovakia	9	9
Total UE27	**5808**	5952

Table 3: Proven reserves of the EU27 for 2011 and 2012 (Source: IEA 2012)

Two-thirds of the oil produced is supplied by the United Kingdom, which is already past its peak oil production point and has been a net importer of oil since 2005. Denmark, the EU's second largest oil-producing country, passed peak oil in 2004 and its production is declining at the rate of 8-10% per year, while Italy and Germany produce only 10% and 5% of their requirements respectively. For its part, Romania passed peak oil in 1973. European oil-producing countries have all passed peak oil, and only Denmark produces more oil than it consumes.

For the past 50 years, Estonia has been extracting kerogen from oil shale and processing it into oil. Although it has major resources (one billion tonnes), the country only produces 3,000 b/d or 16% of its national requirement. The prospects of this technology may seem good at first sight, but it has serious limitations. To begin with, oil shale contains 5 to 10 times less energy than crude oil. Furthermore, a great deal of energy is required to heat the kerogen as well as to pump and treat the water used for this process. The latter's ERoEI rate[1] is therefore very low, ranging from 1 to 5, according to different studies. To this we may add two significant environmental problems: high water consumption (more than one barrel of water per barrel of oil) and greenhouse gas emissions 20% to 75% higher than for crude oil. As a result, this technology cannot be widely adopted.

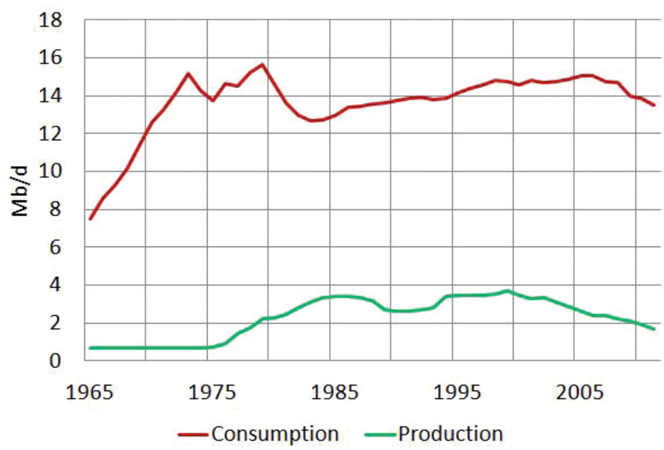

Figure 21: Oil production (excluding biofuels) and consumption of the EU27 (Source: BP 2012)

1. For a definition of the ERoEI, see Part II, Section C.

In recent years, oil companies and many governments have become interested in exploiting shale gas, especially since it is technically possible to process natural gas into liquid fuel. However, it should be emphasised that shale gas is unsuitable as a general replacement for oil, but will, at most, reduce dependency on natural gas imports. To date, this resource is exploited in the United States, but not so in Europe, where only a few operating permits have been recently granted.

	Bcm	Gbpe
Poland	5 600	32,24
France	5 400	31,03
Sweden	1 160	7,07
Denmark	650	3,97
United Kingdom	570	3,45
Romania, Hungary, Bulgaria	540	3,28
Netherlands	480	2,93
Germany	230	1,38
Lithuania	115	0,69
Total UE27	**14 745**	86,03

Table 4: European technically recoverable shale gas resources (Source: IEA, 2011)

While there seem to be substantial resources available (86 billion barrels of petroleum equivalent for the EU), we must qualify our appraisal of the situation on the basis of several criteria, including energy efficiency as well as economic and environmental considerations. In the first place, the processing of gas into liquid hydrocarbons entails a 45% loss of energy, i.e. the loss of almost half of the initial energy. Secondly, the cost-effectiveness of the processing plants depends on the price ratio between gas and oil, i.e. oil must be expensive and gas must be cheap. With the price of an oil barrel in Europe at $100, the price of gas would have to be divided by five for this technology to be a profitable proposition – an unlikely prospect at present. Lastly, there are significant environmental constraints and nuisances, including numerous boreholes, fracturing, intense truck traffic, high consumption/pollution of freshwater, and consumption of sand. Unlike the United States, where production is confined to remote desert areas, in Europe the processing plants would be located close to inhabited areas, which would give rise to concern and protest movements among the local population.

Though steadily on the rise, the production of biofuels will not meet actual needs in terms of timescales, available quantities and net energy requirements, although it is a technically viable process. About 70% of the volume of biofuels consumed in the European Union is constituted by biodiesel, which is made from vegetable oils. At present, this sector is coming under strong competition from South American and Indonesian oils, and this could compromise its

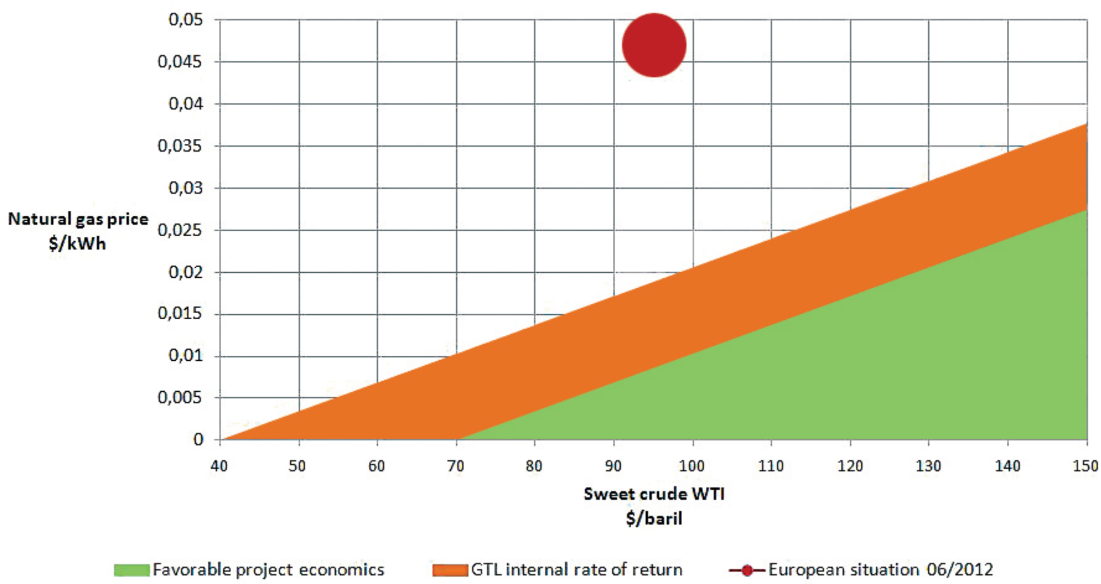

Figure 22: European situation in relation to the cost-effectiveness of a Gas-To-Liquid process. (Chart adapted from the OGJ)

development. Moreover, according to the best estimates available, biofuel production will only cover, by 2020, the equivalent of 3% of the EU's current consumption of crude oil. Biofuels also have a very low ERoEI rate, since the process requires considerable amounts of fossil energy used to mechanise and operate agricultural inputs produced by the petrochemical industry. To these limitations we should add another, which is even more important: competition with the production of food crops on the available agricultural land.

In summary, the global production of liquid fuels will continue to decline sharply in the European Union. No technology seems poised to emerge soon enough as a viable alternative to meet the challenges ahead. Faced with this situation, there are only two possible levers that can be pulled: reduce consumption and/or increase imports.

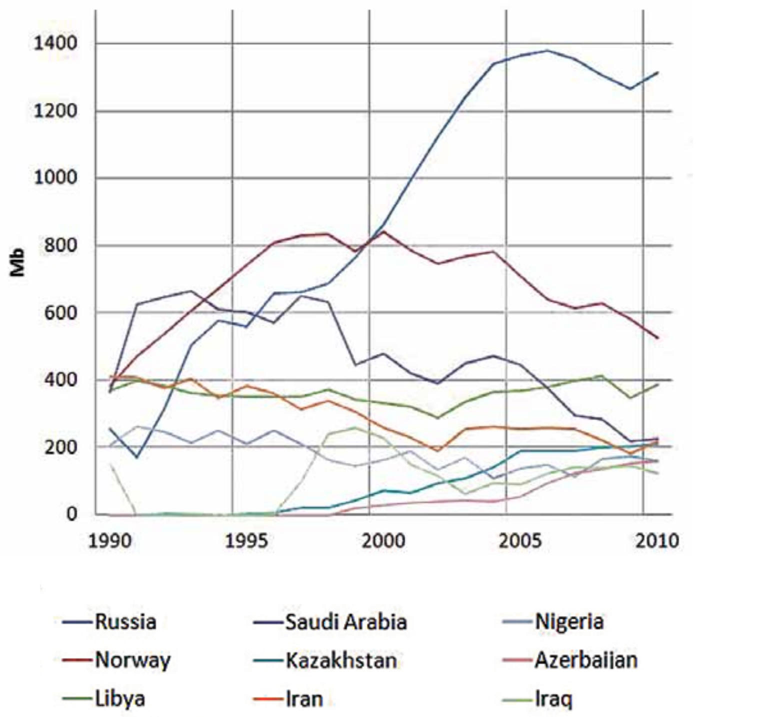

Figure 23: Evolution of the EU27's annual crude oil imports for the main suppliers

C. IMPORTS AND ASSOCIATED RISKS

1. SUPPLIER COUNTRIES

Having long been the European Union's main supplier, the Middle East now 'only' accounts for 27% of imports. Nowadays Russia is the leading country supplying oil to the EU, followed by in second place Norway, with 14% of the EU's oil imports, although the volumes this country supplies have fallen dramatically since its production peak. A final point to note is that imports from the Caspian Sea region have been gradually rising and now account for some 10%.

This general diversification of the EU's supply is making it less vulnerable to interruptions by a supplier. However, a number of Member States (namely, the countries that were part of the former Soviet Union and neighbours of Russia) still depend on one country for all their imports.

Since the late 1980s, the geopolitical context of oil production has changed a lot, in particular since certain major producing countries allowed international companies to access their reserves. Since then, the regulation of prices by the market has gained the upper hand over regulation by OPEC and sometimes it is even difficult for a producing country to know who the end customer of its oil will be. This complexity and the interdependencies of globalisation have greatly reduced the risk of a producing country declaring an embargo like the one of 1973 against an importing country.

1. François Lafargue, Scabreuses relations sino-russes, RiskEnergy, consulted on 06/08/2012, URL: http://www.riskenergy.fr/2012/04/scabreuses-relations-sino-russes.html
2. In 2011, the share of exports to China stood at 15%.

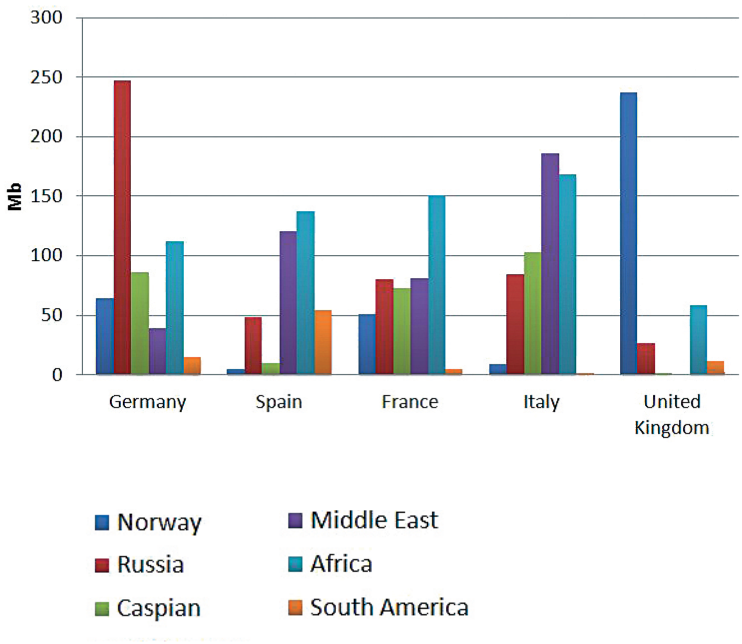

Figure 24: Origin of oil imports in 2010 for the five leading oil consuming countries in the EU

RUSSIA

The geographical proximity of Russia makes it a key trade partner for the European Union, which accounted for 47% of its total revenue in 2010. Russia is the top supplier of oil to the EU, which in turn is a key market for Russia. In 2010, six Member States imported more than 90% of their oil from Russia, and among the EU's leading economies, Belgium, the Netherlands, Greece and Germany imported more than a third of their oil from there. In other words, Russia is – and is set to remain – a crucial partner in the supply of energy to the European Union.

However, Russia has to address two challenges in the years to come: how to maintain its production capacity while taking the best possible advantage of the increased competition for oil. As far as production is concerned, it will have to deal with a marked decline in its main oilfields (Siberia). The potential is definitely there, but the technical and financial difficulties pose significant restrictions. The development of the Arctic is financially and environmentally risky. In spite of the arrival on the scene, since 2000, of international private companies and of investors, the prospects are bleak: even the Russian Minister for the Economy himself announced in September 2012 that production would at best stagnate over the next three years, but that a 3% decrease was more likely.

As regards the competition, Russia needs to increase its market share with the EU and also establish more of a foothold on the Asian and North American markets. The cooperation between Russia and China has increased in recent years, with the volume of financial exchanges rising 43% in 2011. But this cooperation is imbalanced and marked by distrust: Russia is much more dependent on China than China is on Russia: Russia only accounts for 2% of Chinese exports while China is Russia's second biggest supplier[1].This means that China has a dominant commercial position that weighs heavily in negotiations and enables it for example to negotiate reductions on the price of oil. The Russian 'Go East' strategy foresees an increase in exports to China from 3% in 2005[2] to 30% in 2020 (Lifan, 2012). Thanks to the Skovorodino-Daqing pipeline, financed by China, Japan could almost become a major customer for Russian oil.

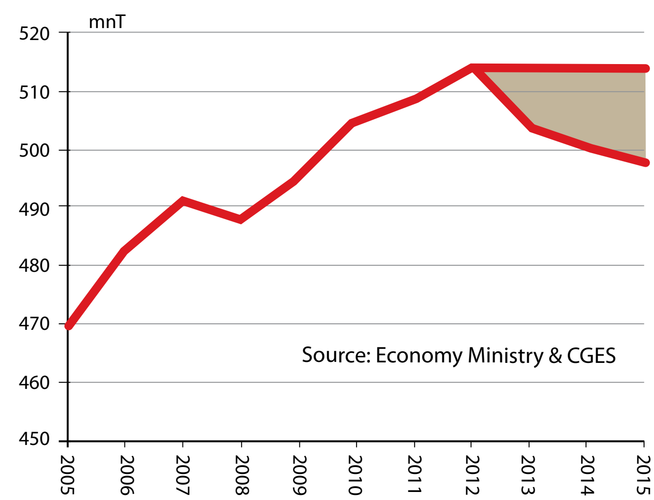

Figure 25: Russia's oil production prospects (in millions of tonnes per annum)

But the dispute between Russia and Japan about the Kuril Islands has formed a continual stumbling block for relations between them since the Second World War and negotiations remain at a standstill to this day.

NORWAY

Norway has rejected joining the European Union in two referendums (1972 and 1994). However, it is cooperating closely with the EU in many domains, including energy. Production fell 33% between 2001 and 2011, and the amount of crude oil imported by the EU from Norway dropped from 840 Mb/year to 450 Mb/year in the same period, i.e. a decrease of 46% in 10 years. Despite this, Norway remains the European Union's second biggest supplier and supplies close to half of the oil consumed in the United Kingdom, 60% of the oil consumed in Ireland and a quarter of oil consumption. In a report in June 2011, the Norwegian Ministry of Petroleum and Energy indicated that production would continue to decline in the years to come (Norwegian Ministry of Petroleum and Energy, 2011). In August 2012, production reached its lowest level for 20 years at 1.6 Mb/d.

Therefore, the European Union cannot rely on Norway much for its future supply and the few Member States that have a high level of dependence on Norwegian oil will have to find other suppliers.

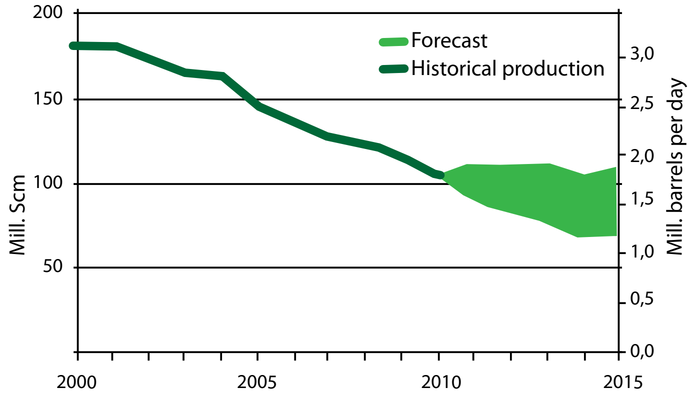

Figure 26: Oil production forecasts for Norway (Source: Norwegian Ministry of Petroleum and Energy, 2011)

MIDDLE EAST

The Middle East has always been the main oil-producing region, with half of proven reserves and one third of global production capacity in 2011 (BP, 2012). As we have seen, the European Union's dependence on the Middle East for oil has steadily decreased since the late 1980s and represented around a quarter of imports in 2011, but it still remains the case that the stability of the global economy depends on this region and its geopolitical development. Yet it is a region with many problems, both between the countries and their leaders and within the countries themselves. Currently, the level of tension can be said to be high, since most of these countries are in conflict situations, what with for example the revolution in Egypt, the civil war in Syria, tensions between religious communities, public demonstrations, the Iran nuclear question, and attacks and sabotage in Iraq. Without embarking here on an analysis of these very complex interconnected situations, it is worth stressing the high level of instability in this area – an instability that is a threat to not only the EU economy, but more generally to global peace and the global economy. Although Europe is less dependent on oil imports from the Middle East than it used to be, it would not be able to avoid the considerable impact of the systemic crisis that would result from the breakout of an open international conflict in this part of the world.

Saudi Arabia, thanks to its immense reserves and its capacity to adjust its production, has long had a 'regulating' role in the region. Therefore, it was the country that made up for the embargo against Iran enacted by the EU in July 2012 by increasing its contribution by around 0.6 Mb/d. However, it has to deal with two major difficulties: political instability associated with the organisation of the succession to the throne and great economic fragility. The heirs to the throne are very old and die shortly after they have been appointed, making stable political administration of the kingdom impossible. Furthermore, Saudi Arabia's 'rentier' economy promotes public expenditure, domestic oil consumption that is rising so dramatically that, if it continues, it will stop exporting oil in 2037, a very strong dependence on imports of consumer goods and a lack of diversity in its revenue. The Arab Spring has not yet reached Saudi Arabia but young people, who form the vast majority of the population, are beginning to voice their anger at the situation. These weaknesses could, in the short or medium term, impact the future of the country's production, oil prices and supplies to the European Union.

Iraq has the five biggest reserves of any country worldwide, with five enormous fields whose volume comes to more than 5 Gb. However, this considerable potential is still largely untapped. According to the IEA, production could reach 6.1 Mb/d in 2020 (IEA, 2012), but there are very substantial hindrances to development: political instability, corruption and insecurity, a lack of skilled labour, logistical barriers and also a continuing glut of obstacles to foreign investment. Moreover, according to the IEA, to maintain the pressure in the oil fields and extend production, they need to be injected with gas or water (which one will vary from case to case). Up to 8 Mb/d of desalinated water will need to be carried from the Gulf to the onshore oilfields in southern Iraq, which will cost a lot of money and take a very long time to get up and running. Although the country's oil production has risen 30% in two years to reach 3 Mb/d, the development of the situation is expected to remain chaotic and unpredictable.

Iran has been a focus of international tension and has been subject to an oil embargo by the European Union since July 2012, due to disagreements about the country's development of nuclear energy. With the fourth largest oil reserves worldwide and as the fifth biggest global producer, Iran is a major player in terms of both oil and gas. However, the country's production is in decline and even in a stable geopolitical climate, exports could be zero by 2020. As things stand at the moment, it is impossible to make a more precise analysis of relations both between Iran and the EU, and between Iran and the rest of the world.

AFRICA

Nigeria, as Africa's leading producer, has strong potential for development, with the government estimating production forecasts of 4 Mb/d. However, this country, 95% of whose export revenue comes from oil, is experiencing serious domestic problems: vandalism, environmental disasters, piracy, kidnappings, thefts and sabotage. Production, at only 2.5 Mb/d, still falls well short of the forecasts.

Libya has the largest reserves in Africa, with 47.1 Gb. While production stopped for seven months during the revolution in 2011, it quickly shot up again when it was restarted, to reach 1.6 Mb/d in July 2012, and is expected to hit 2 Mb/d in 2015 if no problems get in the way.

SOUTH AMERICA

In terms of oil production in South America, two countries stand out from the rest: Brazil and Venezuela. Brazil produces approximately 90% of its oil offshore at very substantial depths under the sea and

1. Reuters, Petrobras needs higher fuel price to invest –CEO, consulted on 13/10/2012, URL: http://www.reuters.com/article/2012/06/15/petrobras-investment-idUSL1E8HFJRS20120615
2. Anne Cheyvialle, L'économie du Venezuela est trop dépendante du pétrole, Lefigaro.fr, consulted on 14/10/2012, URL: http://bourse.lefigaro.fr/devises-matieres-premieres/actu-conseils/l-economie-du-venezuela-est-trop-dependante-du-petrole-292081

most of it is heavy oil. Substantial investments are required and the Brazilian national company Petrobras is set to invest $236 billion between 2012 and 2016[1]. to increase production. Brazil, a big oil consumer, is a net importer and is unlikely to become a major supplier for the European Union.

According to OPEC data, Venezuela has the largest oil reserves of any country in the world, following the integration of its extra-heavy oil into its proven reserves (close to 300 Gb in the Orinoco Belt). Most of the fields being developed are mature and the national company PdVSA (Petróleos de Venezuela SA) has to spend several billion dollars each year just to maintain production at a decline rate of 25% per year. The main potential lies in the Orinoco Belt, where ongoing projects should provide 2 Mb/d of extra production by 2020 (EIA, Analysis brief). The system put in place by President Hugo Chavez, who was re elected in the autumn of 2012, involves using the oil revenue as a major source of funding for social projects (one third of PdVSA's turnover is to be used for social initiatives[2]). Therefore, the development of new production capacities may take place less quickly than importing countries might wish.

1. TRANSPORTING OIL

Transporting oil poses a major geopolitical challenge. Some 80% of crude oil and 90% of traded oil is now transported by sea. Only Russian and Norwegian oil is transported to the European Union via pipeline.

As well as being much cheaper than shipping, pipelines pose fewer risks, except for possible conflicts between a supplier or consumer country and the country through which the oil passes in transit, as was the case when Russia and Ukraine were at loggerheads over the transit costs of natural gas. Russian oil is transported via the Druzhba pipeline, a 4,000 km-long pipeline with a total capacity of 1.64 Mb/d that supplies oil to Poland, Germany, Hungary, Slovakia and the Czech Republic. Norwegian oil is sent via the 345 km-long Norpipe pipeline which provides the UK with 0.9 Mb/d. No investments are planned for this pipeline in the future and there is the risk that the EU may have stopped importing Norwegian oil completely by 2015.

Therefore, the vast majority of oil is transported by sea. Approximately 70% of hydrocarbon trade via tankers takes place on the North Sea and Atlantic Ocean coasts and 30% on the Mediterranean coast thanks to oil terminals, the largest of which

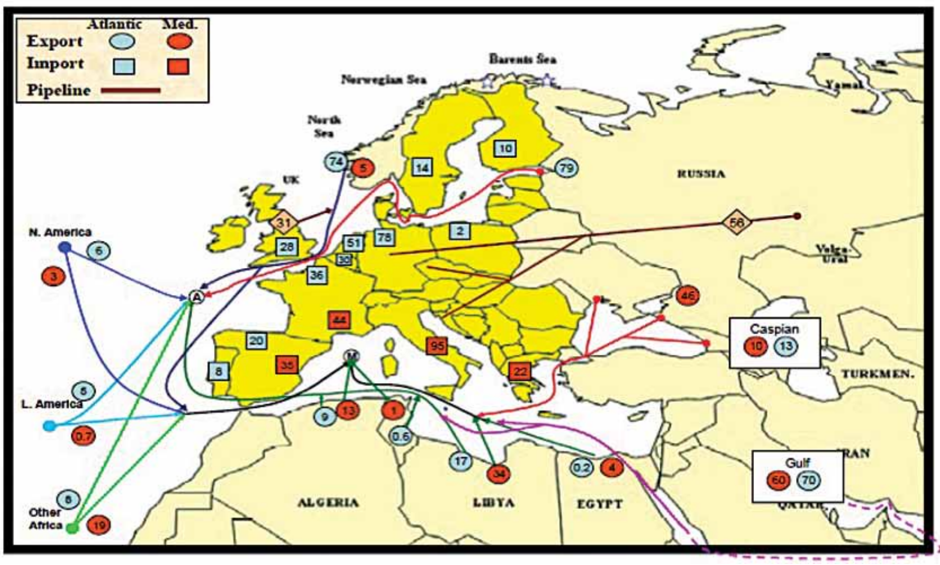

Figure 27: Oil pipeline routes in the EU-27 (Source: Mediterranean Energy Observatory)

(in Rotterdam, Marseille, The Hague, Trieste and Wilhelmshaven) have a total capacity of 5 Mb/d. This type of transport poses major environmental risks (one accident every three years in the EU on average) as well as economic and financial risks in the event of blockages. Straits and channels in particular are sensitive spots, such as the three strategic routes for tankers travelling to Europe from the Middle East: the Strait of Hormuz, the Bab el-Mandeb Strait and the Suez Canal.

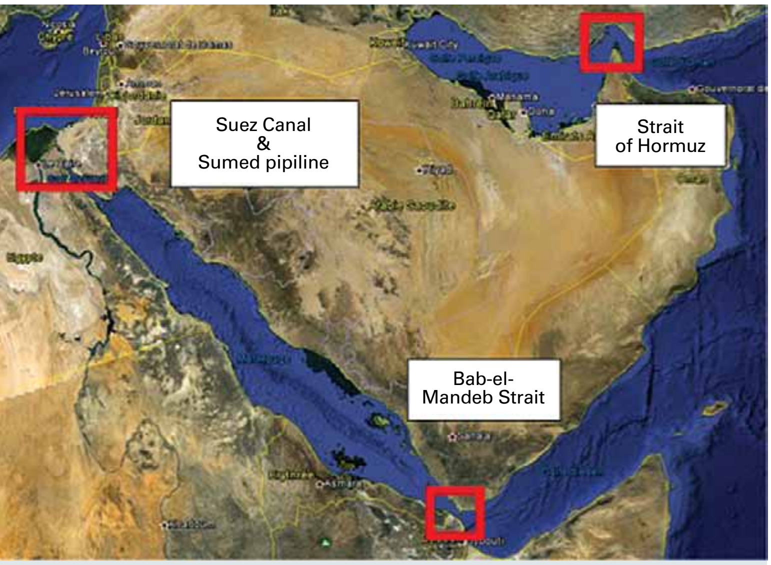

Figure 28: The Strait of Hormuz, the Bab el-Mandeb Strait and the Suez Canal (Google Earth© image)

These routes are strictly monitored (i.e. constant presence of US armed forces) and pose technical, political and terrorist risks. Every day, tankers carrying 17 Mb (20% of the world's crude oil consumption) pass through the **Strait of Hormuz**, which is located between the Persian Gulf and the Sea of Oman. Tensions there are running very high since Iran threatened to block the Strait if it were attacked by Israel or the United States. Such a decision would provoke an immediate response from the United States' armed forces that would overwhelm Iran, particularly since the Strait is located in international waters over which Iran has no rights. Although this consideration reduces the risk somewhat, the international community take Iran's threat seriously. Pipelines through Saudi Arabia, Iraq or the United Arab Emirates may offer a solution bypassing the Strait, but the capacities of these pipelines are still clearly insufficient.

Tankers travelling to Europe and the United States must then pass through the **Bab el-Mandeb** Strait to reach the Suez Canal and avoid having to sail around Africa. The very narrow passage (29 km at its narrowest) is being increasingly targeted by pirates.

A total of 17,800 vessels (a quarter of which were transporting oil) passed through the **Suez Canal** in 2011. The Canal is the last strategic waterway before reaching the EU. The Sumed pipeline has a capacity of 2.4 Mb/d and is an alternative pipeline that was built after the Arab-Israeli Six Day War resulted in the closure of the Canal from 1967 to 1975.

Russian oil is also transported by sea from ports in the Black Sea via the **Bosphorus** and the **Dardanelles**. Located in Turkish territory, these two straits are only 760 metres wide at their narrowest point (at Istanbul) and are one of the most difficult routes in the world to navigate. They pose a number of risks and traffic has risen since Azerbaijan and Kazakhstan increased their oil exports to the EU. In 2011, almost 3 Mb/d were transported in 5,500 tankers. Turkey has introduced increasingly restrictive regulations to improve safety and eliminate all accidents, resulting in long queues. A joint Romanian-Italian pipeline project is underway to relieve congestion on this waterway, but this would be hindered by Slovenia and Croatia.

3. STRATEGIC STOCKS AND THE INTERNATIONAL ENERGY AGENCY

The Six Day War and the closure of the Suez Canal opened Europe's eyes to its vulnerability to disruptions in oil supply. Since 1968, the European Commission has introduced directives for a Community energy policy that focuses on stocks in particular.

Figure 29: Bosphorus and Dardanelles (Google Earth© image)

However, these measures have proven to be inadequate. The OECD founded the International Energy Agency (IEA) in 1974 and signed an agreement on an International Energy Program (IEP). The IEA is a Paris-based independent agency and is crucial for ensuring energy security in Europe. It comprises 28 members, 19 of which are EU Member States (Austria, Belgium, the Czech Republic, Denmark, Finland, France, Hungary, Germany, Greece, Ireland, Italy, Luxembourg, the Netherlands, Poland, Portugal, Slovakia, Spain, Sweden, and the United Kingdom).

The IEP requires member countries to store a volume of oil equal to at least 90 days of consumption based on net imports the previous year. If any country sustains a reduction in its oil supplies at least equal to 7% of the average daily rate, emergency measures will be initiated. The IEP also sets out rules on using stock, reducing demand and, if necessary, sharing available oil to stabilise the markets in the event of disruptions to supplies. If the reduction is lower than 7%, Coordinated Emergency Response Measures (CERM) may be launched to trigger fast and flexible measures, as was the case during the first Gulf War in 1991.

The IEA advises its member countries on energy policy and publishes the World Energy Outlook every year, an overview and prospective study of the energy sector that acts as a point of reference for public and private organisations. However, the IEA's main role involves releasing strategic oil stocks on the market in the event of a major disruption to supplies. Over four billion barrels are currently being stored by member countries, in public stocks and in assets held by private companies (63%). These stocks would maintain consumption at current levels for approximately four months and provide member countries with genuine security. In the event of conflicts or blockages, these reserves would fulfil critical needs (e.g. the army, fire brigade, food production) but would not prevent a drop in economic activity. In 1991, 2.5 Mb/d were been put on the market for three months during the liberation of Kuwait, while 2.1 Mb/d were put on the market in the 30 days after hurricane Katrina in 2005. In 2011, 60 million barrels were released after the beginning of the civil war in Libya, the result of sustained efforts by the USA (50%), Europe (30%) and Asia (20%).

D. KEY SECTORS AT RISK

As we have shown, the decline in the production and overall consumption of oil is imminent. However, the European Union, like all modern economies, is very dependent on this resource and we must ask ourselves what impact this decline will have on our society. Predicting phenomena is extremely complicated, as there are multiple factors and interactions involved and they have not yet been studied in sufficient detail. How will the price of oil influence demand in the future? How will investments change in the face of price volatility? How will this affect energy efficiency and substitution? How will the public react to governments taking over responsibility for the energy situation completely?

When situations are complex, there will always be those who argue in favour of not changing anything. Therefore we need to understand the potential impact of inaction in the specific case of peak oil.

1. http://www.decc.gov.uk/assets/decc/11/about-us/economics-social-research/2934-decc-oil-price-projections.pdf
2. Charles Maxwell, Weeden's Maxwell: Brace for $300/barrel oil, IndexUniverse, consulted on 27/08/2012, URL: http://www.indexuniverse.com/sections/interviews/8360-eedens-maxwell-brace-for-300barrel-oil.html
3. Energy intensity has been in decline in Europe since 2009, which exacerbates the impact of energy prices on the economy.
4. Oil intensity is the link between the quantity of oil consumed and GDP. It helps assess an economic organisation's dependence on oil.

We have decided to illustrate this by predicting the effects of a significant rise in oil prices, which would be an overwhelming economic constraint. Most energy scenarios suggest that the price of hydrocarbons will rise (amounts differ from author to author). In late 2011, the UK's Department for Energy and Climate Change (DECC)[1] compiled a document listing the various reference scenarios that gave a margin of between $92 and $135/barrel by 2020, while other scenarios suggest that prices could be as high as $300[2] to $400/barrel. It is no longer possible to predict oil prices in the long-term; history has shown that prices have been known to significantly surpass all predictions within a short amount of time. It is also impossible to anticipate a permanent rise, as the industrial and globalised system only has a limited capacity to offset very high oil prices.

1. ECONOMY

Several studies concluded that the link between economic growth and oil prices had become increasingly tenuous and that the latter had virtually zero impact on the economy. This analysis was true until 2009[3] for OECD countries that relocated their energy-intensive, polluting and high oil-intensity activities[4], but was much less so for emerging countries and the global economy as a whole. Yves Cochet had explained this concept in 2005 (Cochet, 2005, p. 106), saying that France's imperviousness to changes in oil prices was a myth.

At $200/barrel…

When production costs rise, companies invest less and create less wealth. At national level, the hike in oil prices ultimately affects private-sector wages and profits. Add to this inflation and the rise in energy costs, and domestic demand may fall by between 30 and 40%. The surge in consumer prices for households means that wages have to be renegotiated, reducing margins further. Lastly, the fall in consumption and higher costs make jobs less profitable for companies, resulting in an overall decline in the demand for labour, in spite of some activity being transferred to less energy-intensive sectors. Investment and consumption shrink, triggering recflation, or recession combined with inflation, where prices rise but there is no growth. This affects all sectors, even those that are vital to ensuring that society runs smoothly. The poorest are hit earlier and harder, as they do not have any room for manoeuvre, and unemployment, shortages, bankruptcies and defaulted debt become common occurrences.

2. FOOD

There are significant risks throughout the food chain. Agricultural production is highly dependent on machinery and inputs from the petrochemical sector. In the agricultural sector, humans have been replaced by machines, the ground is now covered by synthetic fertilizers instead of organic matter, and biocides are being used to 'standardise' the environment by changing any specific varieties grown according to the area's characteristics. Therefore reliance on fossil energies is rising and food prices are again being indexed against oil prices. On average, energy, fertilizers and biocides account for 20 to 25% of the variable expenses paid by European farm owners, and up to 46% in the case of large-scale farms in France (Agreste, 2009).

1. Agricultural statistics from the European Commission, consulted on 07/10/2012, URL : http://ec.europa.eu/agriculture/statistics/agricultural/2011/pdf/tables-maps-graphs_en.pdf

Changes in these costs are directly linked to those in oil prices, as shown in 2007 by the 15.7% rise in the price of fertilizers (INSEE, 2012) manufactured from natural gas, which is directly indexed against the price of oil in Europe.

Another high-risk sector is the fisheries industry. Fuel expenditure rose from 15 to 24% between 2004 to 2008, and between 30 and 40% of fleet segments suffered financial losses each year during this four-year period. Fishing is an at-risk sector that has not adapted to the increased scarcity of oil, as boats are old (26 years on average) and an average of 200 litres of oil is consumed per metric ton of fish caught.

	Total variable expenses	Energy and lubricants		Fertilizers		Biocides	
	€ (mil.)	%	€ (mil.)	%	€ (mil.)	%	€ (mil.)
EU-27	**212891**	**12,2**	**25973**	**6,9**	**14689**	**4,7**	**10006**
France	39479	8,7	3435	8,1	3198	6,9	2724
Germany	32120	11,2	3597	6,6	2120	4,7	1510
Italy	20959	11,7	2452	5,8	1216	3,9	817
The Netherlands	16069	14,7	2362	2,2	354	2,7	434
United Kingdom	15679	9,3	1458	10,0	1568	5,3	831

Table 5: Distribution of variable expenses, the cost of which is linked to oil prices, as at 2010 (Source: European Commission[1])

Thus the entire food system is structured around the low cost of energy, i.e. the loss of local self-sufficiency, the appearance of regional specialities in some cultures, the increase in size in operations and cuts in the work-force. Eating habits (e.g. out-of-season produce, exotic foods) have also changed, resulting in massive import and export flows only possible thanks to the low cost of transport in a complex and globalised logistics system. For example, Europe exported 2.8 million tons of milk and imported 1.6 million tons in 2009.

At $200/barrel…

In 2008, a 17% surge in the price of agricultural produce triggered a 10% increase in food prices. During the same period, the price of a barrel of oil rose by approximately 85%. Consequently, if the price of a barrel were to double, the price of agricultural produce may rise by 20% compared with 2012 prices and consumer prices may increase by between 12 and 15%. Restricted access to inputs and fossil energies would prompt a slump in agricultural yield as arable land would be exhausted from decades of chemical-intensive agriculture, varieties specific to certain areas would have disappeared and agricultural training would not have passed on enough organic techniques that were less energy intensive. A real food crisis would arise owing to the combination of price rises and the physical shortage of food, causing delinquency and riots.

In the fisheries sector, many fleets will cease to operate and there will be shortages in the markets and in the agro-food industry. This will directly affect 250,000 people in total. Port economies will be hit by industrial action, with major consequences.

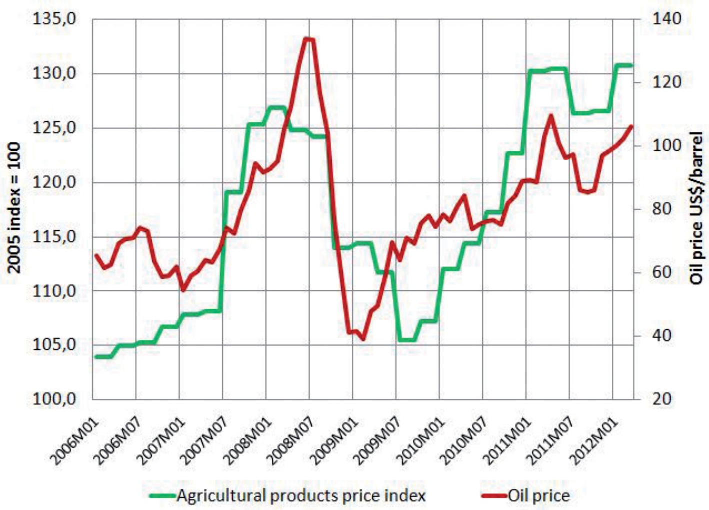

Figure 30: Correlation between the price of agricultural produce in the EU-27 and the barrel price (Source: Eurostat)

The main at-risk countries are Spain, Italy and Greece, which account for 60% of the workforce in the fisheries sector, as well as Portugal, France and the UK, which represent 25% of the workforce.

3. HEALTH

The structure of healthcare systems in Europe is also dependent on the low cost of oil. **Transport**, the greatest consumer of energy, is the most problematic, e.g. shipping medication and organs, transporting doctors and nurses to carry out home visits, emergency transport and ambulances, and transportation in connection with health-inspection visits. All of this may significantly increase health expenditure and may disrupt services if money runs out. The lack of doctors and the closure of small healthcare facilities in rural areas force the people in these areas to travel, putting them at risk, so insufficient access to healthcare tends to be a factor in the decline of public health.

Furthermore, oil and its derivatives are used to produce a number of **medicines**, such as aspirin, some antibiotics, nitrogen mustard (used to treat cancer) as well as a number of antihistamines and psychotropic medicines. Tablet binding agents, pill coatings, caps and other types of packaging also contain petrochemical derivatives. Only a small amount of oil products are used here and oil prices only have a marginal impact on the price of medicines. Alternative solutions for producing this type of molecule do exist but there may be temporary interruptions in the supply while the sector is being restructured. A lot of **equipment** and consumables are also produced using oil (e.g. prosthetics, syringes, radiology materials, drips and dialysis tubes, catheters, drip bags, surgical gloves, lubricants, alcohol, toothbrushes), plus excessive packaging and constant use of disposable products. There is a major risk of a surge in manufacturing costs and delays in the supply or even shortages of some products (Frumkin, Hess, & Vindigni, 2009), as was the case following the 1973 oil embargo.

As for **energy**, ensuring the continuity of the energy supply to healthcare equipment is essential, although many hospitals use diesel oil or natural gas gensets. Institutions equipped with collective boilers that run on fuel may see their energy bills skyrocket in years to come.

At $200/barrel…

The effects of very high oil prices on health are numerous and difficult to quantify. If the cost of a reliable energy supply rises, the risk of energy poverty will grow and the health of the poorest people will deteriorate. For financial reasons, increasing numbers of citizens have stopped taking out health insurance, have stopped going to their doctor, or can no longer travel to healthcare institutions. Numerous company bankruptcies, disruptions in the supply of food, energy and health products, interruptions in transport services, as well as family worries trigger persistent stress and wear down peoples' mental health. Deteriorating living conditions and lack of access to the most basic of resources may trigger a rise in domestic violence as well as unrest at regional, national and international level, with possible armed conflicts already being a major factor in the deterioration of human health.

1. http://www.precarite-energetique.org

2. Eric Fishhaut, Petrochemicals firms take a stand against oil price volatility, Market focus, consulted on 24/08/2012, URL: http://www.gvsi.com/download/editorials/Mrktfocs-May-03.pdf

4. ACCOMMODATION

The residential sector is the third largest energy consumer in the EU: oil is burned in boilers for heat or hot water. Gas, the price of which is indexed against the price of oil, now accounts for 40% of energy used in accommodation, while oil represents only 14%. Over two-thirds of jobs in Europe are in the tertiary sector, which means having to insulate heat and maintain a lot of buildings, including those used for public services (e.g. town halls, hospitals, schools, barracks). Moreover, energy poverty affects between 10 and 25% of Europe's population, primarily the retired, the poor, single-parent families, and people living in badly-insulated homes or with inadequate heating facilities. A quarter of the population in Europe lives in rural areas, where more cost-efficient collective heating networks are rare, so boilers fed by oil and storage tanks are commonplace. As a result, the energy costs of these households are 10% higher than those in urban areas. This higher risk linked to living in rural areas is combined with greater dependence on private vehicles.

At $200/barrel…

Energy poverty is the main consequence of the surge in energy prices. Growing numbers of households have stopped turning on their heating, and family homes and health are deteriorating. The number of households living in energy poverty has risen from 15% to between 30 and 40% according to a study on energy poverty in Europe[1]. As gas and oil prices are very high, people are looking into alternative solutions. Power cuts during peak consumption times are more common and backup oil-fired thermal power stations are no longer an option. In emergencies, a number of households are turning to burning wood, the only easily-accessible resource for generating heat. As a result, forests suffer radical cuts such as those introduced in Greece in 2011 and poor-quality stoves create more air pollution. More and more households are struggling to pay their bills and loan conditions from banks are becoming tougher, thus limiting access to properties.

5. PETROCHEMISTRY

The petrochemical sector is a key component of life in Europe, being responsible for latex, plastic, various medicines, cosmetics, detergents, types of packaging, colourings and fertilizers and biocides for agricultural purposes. Oil accounts for approximately one third of this industrial sector's intermediary consumption, so the correlation between the price of these products and the price of a barrel of oil is significant. If the price of oil doubles, the **cost of these everyday items** could increase by between **80%[2] and 100%**. Key sectors such as healthcare institutions and farms would be hit hard since they would see their bills rise considerably, as would end consumers, who would be forced to bear the brunt of this rise.

6. TRANSPORT

Transport is essential to ensuring that society runs smoothly. Oil enables people to travel further, faster and more frequently; as a result, 96% of transport in Europe relies on oil. Over nine million people work in the transport sector, two million in the automobile industry, and 500,000 in aircraft manufacturing, not counting the many spinoff and indirect jobs created by the sector. Therefore tens of millions of people depend on this economic sector, which has become essential for everyone who uses the goods and services it provides every day.

A) AVIATION

A recent report drawn up by the European Commission sets out ambitious aims for the aviation sector, such as enabling travellers to journey between any two destinations in Europe in under four hours 'door-to-door' or multiplying the number of yearly flights by six by 2050 (European Commission, 2011).

1. Florentin Collomp, Airbus optimiste pour l'essor du trafic aérien, Le figaro, consulted on 05/09/2012, URL: http://www.lefigaro.fr/societes/2012/09/04/20005-20120904ARTFIG00541-airbus-optimiste-pour-l-essor-du-trafic-aerien.php

2. Scott Mayerowitz, Airline costs force fares higher, The post and Courier, consulted on 05/09/2012, URL: http://www.postandcourier.com/article/20110605/PC05/306059966

A short while ago, the Airbus COO announced that the company expects to double its fleet in service and predicts a 150% rise in air traffic over the next 20 years[1]. If the gross price of oil, and thus of aviation fuel, doubles, the reality will be very different.

In the early 2000s, fuel represented approximately 15% of airline operation costs. A decade on, this has risen to 35% (45% for long-haul flights), making it the largest area of expenditure, followed by staff costs (28%)[2]. As there are no taxes on aviation fuel, in order to encourage international competition, air travel in industrialised countries is cheap and democratic to a certain extent, but this does not cushion major fluctuations in the gross price of oil. Based on prices for 2012, the International Air Transport Association (IATA) predicts that European companies will suffer a cumulated annual loss of $1.1 billion.

At $200/barrel…

Fuel accounts for up to 70% of operating costs and this increase inevitably has an impact on ticket prices, such as the €200 surcharge applied to flights longer than seven hours introduced by British Airways and Air France in 2012. Poorer travellers will no longer take flights, others will buy seats in economy class and passengers on domestic routes will take the train. Fixed aviation costs (e.g. for airports, air traffic control and other services) are thus passed on to a lower number of travellers, which again increases the price of their ticket. In Europe, the 400,000 jobs directly created by airlines are gradually disappearing, as demonstrated by the recent bankruptcy of Hungarian airline Malev and the Spanish airline Spanair. This may affect a total of 5.1 million jobs in the aviation sector.

Aviation sector professionals are asking governments for their support, given that this sector is vital for the economy, tourism, employment and the transportation of goods. The service life of planes has been extended and construction orders for planes have been cancelled. The aircraft manufacturing sector, which employs almost 500,000 people (a third of whom are based in France) is consequently faced with the same difficulties. The French region of Midi-Pyrénées has been hit particularly hard, as Airbus' presence in this area has generated over 50,000 direct, indirect or spinoff jobs.

B) AUTOMOBILE

Three-quarters of all passenger journeys are by car, with an estimated 236 million vehicles on the road. Partial solutions (such as hybrid or electric cars) may be viable, but only to a small degree; no alternative solution offers the same benefits (e.g. power, independence) as a car with a combustion engine.

Citizen mobility. In 2009, each European citizen spent in average of €1,800 on transport, i.e. 13% of household expenditure. This does not have a significant impact on people living in urban areas or areas served by public transport services. In contrast, those who live some distance from businesses, their workplace and public services, as well as families with shared custody of children are particularly affected by the price of fuel and the cost of keeping vehicles roadworthy.

Automobile industry and sales. The automobile industry (e.g. manufacturing, sales, servicing) accounts for 12 million jobs, 5% of the total EU workforce. A quarter of cars sold around the world are manufactured in the EU's largest economies, which creates 775,000 direct jobs in Germany, 220,000 in France and over 100,000 in Italy, the UK, Spain, Poland and the Czech Republic. Since the 2008 crisis, annual sales have fallen by 16%, a downward trend that looks set to continue. Asian markets currently make up most of the client base for European manufacturers.

At $200/barrel…

The high level of fuel tax in Europe offsets fluctuations in gross oil prices, so European consumers are less affected by the hike in oil prices than US consumers, but the impact is still substantial. Employees continue to go to work, which remains their priority despite the high price of petrol. Queues at petrol stations and rationing may make travel impossible. Car-pooling is growing in popularity and public transport no longer meets travellers' needs. Cycling is once again the most common method of transport for distances under 5 km. Households spending a considerable amount of their budget on energy do not have enough purchasing power to consume and thus cannot spur on growth.

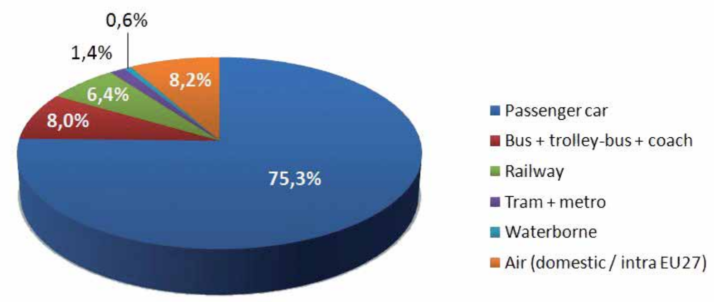

Figure 31: Pie chart of modes of passenger transport in EU-27 in 2009 (Source: European Commission)

In spite of incentive policies put forward by governments, they have stopped investing in new types of vehicles. Decline in demand is getting worse and lack of foresight in the sector is resulting in growing numbers of redundancy programmes and factory closures, triggering major crises in the affected regions.

C) ROAD FREIGHT

Any growth in economic activity means a rise in freight traffic and the associated consumption of oil. In the European Union, three-quarters of goods are currently transported by road and fuel accounts for between 25 and 35% of related costs for carrier companies. The problem seems difficult to solve given the lack of short-term solutions for alternative methods of transport, so cutting oil consumption would mean reducing the amount of transported goods and thus a slowdown in economic activity.

At $200/barrel…

Road freight costs have risen by at least 10%, while the distances travelled and trade between EU Member States are falling. The just-in-time logistics model has been called into question, with some arguing in favour of storage. Company bankruptcies are becoming more commonplace and the sector can no longer support economic activity. Concerns have been raised about the distribution of food, which is very dependent on transport and the logistics sector.

7. IT AND COMMUNICATION

The Internet has radically changed how we communicate, distribute, handle and store information. It is a vital tool for companies, public services, finance and a vast number of citizens. Although use of computers and the Internet does not directly consume oil, it nevertheless accounts for 2% of all electricity generated around the world.

At $200/barrel…

Significant increases in energy consumption (accommodation) are jeopardising the stability of the electricity grid, regularly disrupting telecommunications services. The creation, distribution and maintenance of these systems is also facing difficulties, as are all companies in this sector, be they SMEs or major companies listed on the stock exchange.

V. CONCLUSION

The main conclusions of this report are as follows:

- **The probability** of bringing together all the essential conditions that would allow **the increase in production to be extended beyond 2020 is very low**. On paper, this ideal case scenario is only possible if the political instability of the producing countries is eliminated, if investments grow and technology overcomes all the physical barriers facing it (however, it must be borne in mind that the environmental constraints are not going anywhere). This is the situation some authors describe in their publications, concluding that steady oil consumption will still be possible for 50, 100 or even 200 years yet and that there is no cause for concern. We do not share this view and believe that this hypothesis should not be given much weight in policy-making.

- **The likelihood of a reduction in the oil supply by 2020 is very high:** a whole host of factors will probably lead to an imminent decline in global oil production, among them lack of investments, conflicts, social movements, environmental disasters and a rapid decline in the fields that are currently producing oil. Despite the very likely nature of this scenario and its potential impact on the European Union, insufficient account is taken of it in public policies.

- **There is a physical limit on the development of oil resources.** Contrary to some traditional thinking, it is not only the oil price that puts a limit on development of the resources – there is also the ERoEI. This must total more than 10 to enable an industrialised society to work properly. This means that as the global economy currently operates, it could not be sustained only by the development of tar sands, shale oil and biofuels because these resources would make insufficient net energy available to society.

- **The economy is subject to the availability and price of oil.** In spite of heavy taxation, energy efficiency and replacement with other forms of energy, the economy is still subject to the vagaries of oil production and supply. In 2012, the global economy is in crisis largely because of the high oil price. Indeed, the only two factors capable of reducing the price are the recession and Saudi Arabia, the only country able to increase its production from one day to the next. Oil remains the lifeblood of the global economy and this should be borne in mind when analysing its fluctuations.

1. 2020 targets: increase the share of renewable energies by 20%, reduce greenhouse gas emissions by 20%, improve energy efficiency by 20%.

- **The European Union is very vulnerable to an energy shock.** We have envisaged a few effects of peak oil on the European Union, which we know will be considerable. The economic, food, health, housing, transport and communications sectors – i.e. all the sectors essential to the smooth running of a society – have become directly or indirectly dependent on oil and risk, in the absence of forward thinking, being rocked by a situation in which demand outstrips supply.

- **The European Union has virtually no more oil of its own** and by 2020 it will be dependent on imports for 90% of its supply. However, judging by the EU's '20-20-20[1]' strategy, which sets inadequate targets for 2020, the gravity of the situation does not appear to have hit home. Yet this is an ambitious plan given the current economic situation of the European Union and the strong sense of inertia gripping the EU, especially if it is not applied as part of a mass reorganisation of the major sectors. However, it is above all inadequate because it does not call into question the European Union's dependence on oil, nor does it take into account the possibility of a decline in global production by 2020 or the scale of the impact of this development.

The Member States of the European Union face a real challenge in terms of energy prudence. They need to show forward thinking by accepting the reality of the physical limits on access to energy. Against the background of a globalised economy, committing to a transitional plan which would be limited to the borders of the European Union may seem overly complex or even impossible, but the potential impact of ignoring the problem or adopting a passive attitude will be infinitely more costly for the population, democracy and the environment. Taking the opposite approach, of mobilising citizens and using all the available tools (energy, companies, capital, materials, etc.) to promote re-localisation, diversification, innovation and conversion could restore some purpose to collective action in the current climate of crisis and improve the EU's adaptability and resilience. The transition to a post-oil society is inevitable, so governments must give their citizens the chance to take the initiative today, so that they do not have to suffer the consequences.

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GLOSSARY OF TERMS

TECHNICAL TERMS

TERM	DEFINITION
Biofuel	Liquid fuel produced from biomass conversion.
Coal, Gas and Biomass to Liquid	Liquid fuel produced from the thermochemical conversion of coal, natural gas or biomass.
Condensate	Very light hydrocarbon, which is gaseous when underground but condenses at wellheads.
Depletion	Share of ultimate recoverable reserves already produced
Shale oil and gas	Gas trapped in the non-porous, impermeable bedrock
Tight oil and gas	Gas contained in very poor compact fields
Coal Bed Methane (CBM)	Gas produced from layers of coal that are too deep or of too poor quality to be developed using mining techniques
Natural gas	Methane found naturally in reservoir rocks
Field	Area forming one or more reservoirs of oil that are part of the same geological structure
Hydrocarbon	Organic molecule consisting of atoms of carbon and hydrogen
Crude oil	Naturally-occurring liquid hydrocarbon found in natural underground reservoirs
Conventional oil	In this study, conventional oil does not encompass extra-heavy oils, deep and ultra-deep offshore oil, tight oil and shale oil
Heavy oil	Heavy oil with a density of between 10°API and 20°API
Extra-heavy oil	Extra-heavy oil with a density less than 10°API
Gas hydrate	Mixture of water and methane trapped on the seabed or in permafrost that crystallises and becomes solid at certain pressures and temperatures
Kerogen	Organic matter that has not been heated to the correct temperature to turn into oil
Oil shale	Sedimentary rock containing immature organic matter (kerogen)
Oil sands, tar sands	Sands containing extra-heavy oil or bitumen
Decline rate	Annual rate at which production at an oil well, field or region declines following the production peak
All-liquids	Generic term encompassing all liquid hydrocarbons and fuels (gross conventional and non-conventional oil, condensates, natural gas liquids, Biomass to Liquid, Gas to Liquid, Coal to Liquid and biofuels)

ABBREVIATIONS

IEA	International Energy Agency
BP	British Petroleum (oil company)
BTL,GTL,CTL	Biomass to Liquid, Gas to Liquid, Coal to Liquid
EIA	Energy Information Administration
EOR	Enhanced Oil Recovery
ERoEI	Energy Return on Energy Invested
ERR	Economically Recoverable Resources
OGJ	Oil & Gas Journal
OPEC	Organisation of Petroleum Exporting Countries
GDP	Gross domestic product
R/P	Reserves-to-production
TRR	Technically Recoverable Resources
URR	Ultimate Recoverable Resources

UNITS

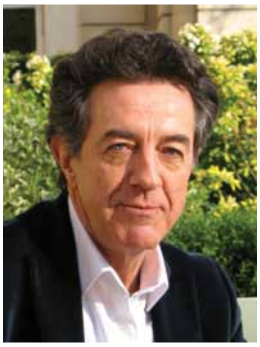
$, M$, Md$	dollar, million dollars, billion dollars
€, M€, Md€	euro, million euro, billion euro
b, kb, Mb, Gb	barrel, thousand barrels, million barrels, billion barrels
b/d, kb/d, Mb/d	barrel per day, thousand barrels per day, million barrels per day
Wh, kWh	Watt-hour, kiloWatt-hour
Bcf, Tcf	billion cubic feet, trillion cubic feet
Bcm, Tcm	billion cubic metres, trillion cubic metres
t, Mt	tonne, million tonnes
°API	API gravity degree (unit for measuring the density of oil
toe, ktoe, Mtoe	tonne of oil equivalent, thousand tonnes of oil equivalent, million tonnes of oil equivalent

Biography - Benoît Thévard
Author of this study

After several years in the aeronautics industry, the importance of what's at stake in the energy sector lead Mr. Thévard back to university in 2006. After publishing several studies on energy at regional level, he worked on solar photovoltaics, while carrying out research on peak oil and territorial resilience.

Since 2010 and the creation of his peak oil awareness blog (www.avenir-sans-petrole.org) he carried out nearly 100 conferences in France (Assemblée Nationale, Science Po', École Normale Supérieure) or in local or regional settings.

He started an alert initiative on peak oil, signed by numerous experts in the framework of the 2012 French presidential campaign. He is a member of the Momentum Institute, a local transition initiative, of the Virage Energie Centre association. He is co-writing a book on the opportunity of improvement of local resilience in the context of current and future crises.



Biography - Yves Cochet

This study was commissioned by Yves Cochet, Green Member of the European Parliament.

Yves Cochet is a French MEP, member of the Green group. In France, he was one of the founders of the first Green party.

After an academic career as a mathematics professor at the University of Rennes, he became one of the first French Green MEPs at the European Parliament in 1989. Then he was elected as a Member of the French parliament, the "Assemblée nationale", in 1997. In 2001, he became Minister of the Environment in the Lionel Jospin government. He remained a national member of the French Parliament until the end of 2011 when he became a MEP.

He wrote many books on Ecology and Peak oil, such as "Sauver la terre", "Petrole apocalypse", or "Anti-manuel d'Ecologie".

NOTES

NOTES

Europe face peak oil

The European Union faces one of its greatest ever challenges: preparing for a post-oil society.

Oil enabled Europe to become one of the richest economies on the planet. Our continent is the world's second largest consumer of oil, yet its oil production has halved since 1999. Today it only meets 13% of its needs, and soon the European Union will be importing all the oil it consumes. Taking a broader view, since the 1980s the world has been consuming more oil than it has found.

Any assessment of the world's oil reserves will inevitably be inaccurate, due to the number of operators, the confidential nature of some data and the technical complexity of the associated calculations.

So what are Europe's energy prospects? The continent's economy is already suffering under the high price of oil, so what will happen over the months and years to come, when prices rise even higher and we may even have to contend with disrupted supplies? How will European governments manage to rethink citizens' access to the most essential goods and services?

This study was commissioned by the Greens/EFA Group in the European Parliament. www.greens-efa.eu
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