INTERNATIONAL RELATIONS

DEPARTMENT FÜR EUROPÄISCHE INTEGRATION
UND WIRTSCHAFTSRECHT

Master-Thesis

zur Erlangung des Titels M.A. (Master of Arts)
im Rahmen des Universitätslehrganges „International Relations“

Peak Oil – Impacts on Global Trade

eingereicht am 25. Mai 2012
Department für Europäische Integration und Wirtschaftsrecht

unter Betreuung von
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von

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Affirmation

I, David Herold, MBA born on December 2^{nd}, 1976 in Frankfurt/Main affirm,

1. that I composed my Master-Thesis independently, using no sources, resources or aids other than those mentioned;

2. that I have not previously submitted my Master Thesis as an examination paper in Austria or any other country;

3. that, if my composition concerns my company of employment, my employer has approved the title, form and contents of my Master Thesis.

Vienna, May 25th, 2012

Preface

The topic of energy and transportation has consumed me for the many years. After starting to work for the Express Cargo Industry, I always wondered about the future of our business. In this context, oil as a definite resource is so important to our lives and our business that I wanted to learn more about it.
I have to admit that I underestimated the huge amount of information provided by various sources with regard to Oil and Peak Oil. Remarkably, I couldn't find any publication or study which analyzed in detail the relations between Peak Oil and transportation. This work is a first approach to close that gap.
Oil is used in so many products, we are actually wasting it. My personal opinion is that the threat of high oil prices – or Peak Oil – is a heavily underestimated risk to our industry and to our living standards. Although everybody knows that oil is a definite fossil resource, mankind takes it for granted that oil or energy is always available to affordable prices. The general assumption is that if oil runs out or gets too expensive, the industry just opens some drawers and presents an alternative energy solution. This will not be the case.

Peak Oil and transportation are affecting global trade, so the approach to this is truly global. And because it affects so many stakeholders, the publications, studies and reports represent various industry and political interests. The more thoroughly I looked, the more I found out that concerning oil, there is very little reliable public data and almost no public discourse. In this work, I focused on oil and its energy use for transportation. For alternative energy, it means only considering those forms that can substitute for oil as a mobile fuel – no wind, hydro, solar, or nuclear power, which provide stationary energy.

As I write these words, the world faces high oil prices and is in the development phase for alternative energy sources. Nothing fast will happen, so I am convinced the issue with Peak Oil and transportation will keep us busy for many years to come.

Among all publications and assessments of international institutions and industry organizations, I would like to highlight the books of Pulitzer Prize Winner Daniel Yergin, which provides a profound view about oil and energy today. For the transportation part, I relied heavily on the assessments of Jean-Paul Rodrique, Claude Comtois and Brian Slack in the book “The Geography of Transport Systems”. Furthermore, the BP Annual Review played a huge role in understanding the complexity of numbers of demand and supply. One of the biggest challenges was to consolidate the information which is essential and fundamental to Peak Oil, transportation and global trade. It was hard to find the balance between an information overload and integrating all relevant aspects to this topic.

I owe thanks to many people, who helped me with analysis, reports and ideas. In particular, thanks to my colleague Christoph Bairaktaridis for supporting me, the insights from Alexander Slovak from Gebrueder Weiss with regard to transportation integration and last, but not least my company FedEx for giving me the opportunity to study and broaden my horizon while working and to experience the topics that I am writing about on a daily basis.

David Herold
May 2012

List of Acronyms and Abbreviations

bbl	Barrel
BP	British Petroleum
CAREX	Cargo Rail Express
CEO	Chief Executive Officer
CNG	Compressed Natural Gas
CO2	Carbon Dioxide
EIA	US Energy Information Administration
EU ETS	European Union Emissions Trading Scheme
EU	European Union
FSU	Former Soviet Union
GDP	Gross Domestic Product
IEA	International Energy Agency
IMF	International Monetary Fund
IOC	International Oil Companies
ITS	Intelligent Transport System
JODI	Joint Oil Data Initiative
LNG	Liquefied Natural Gas
mb/d	million barrels per day
NAFTA	North American Free Trade Agreement
NOC	National Oil Companies
OECD	Organisation for Economic Co-Operation and Development
OPEC	Organization of the Petroleum Exporting Countries
R&D	Research & Development
Rep.	Representative (U.S. Representative)
SEC	Security Exchange Commission
SES	Single European Sky
SUV	Sport Utility Vehicle
URR	Ultimately Recoverable Reserves
U.S.	United States
USD	US Dollar

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1 Introduction

1.1 Background

Over the last several decades the world has been characterized by increasing dependence among nations. This interdependency – what we call globalization today – is a multi-layered and complex phenomenon involving intensive political, social and economic interaction, both nationally and internationally.

Global trade is integral to the process of globalization. Over many years, governments in most countries have increasingly opened their economies to international trade, whether through multilateral trading systems, increased regional cooperation or as part of domestic reform programs. Trade and globalization more generally have brought enormous benefits to many countries and citizens. Trade has allowed nations to benefit from specialization and economies to produce at more efficient scale.

Chief among the technological drivers of globalization are inventions that have improved the speed of transportation and lowered their costs. These include the development of the jet engine, containerization in international shipping and the revolution in information and communication technology. In the new economic geography literature, the size of trade costs is a major determinant in the decision of companies on where to locate. In the literature on international fragmentation of production, trade costs have been seen as influencing the choice between out-sourcing or in-sourcing, and sourcing through intra firm or arm's-length trade.

Consequently, transportation is often referred to as an enabling factor that is not necessarily the cause of international trade, but as a condition without which globalization could not have occurred.

Additionally, the recent years have brought a great deal of turmoil and instability to the global oil market. While oil prices impact global economy at large they impose a particular burden on global trade. The important question is whether the world is at the outset of a new era in which oil output is nearing its peak and will no longer be sufficient to meet global demand.

Forecasting the future of oil has always been a challenging task. The reason is that most of the world's oil reserves are concentrated in the hands of governments which provide very little access to their field by field reserve data and resist privatization of their oil industry and foreign investment in their countries. It can also not be predicted, how far we are from peak oil, the point in which half of the world's cheaply recoverable oil has been depleted and from where prices never go down.

Global trade itself is poised to be the prime casualty of the new era of expensive oil. The volatility in oil prices in recent years is taking global trade into uncharted territory, raising questions about the economic viability of many players in the industry.

1.2 Objective

This Master thesis attempts to describe future scenarios of trade and transportation with regard to high oil prices. It provides on overview of the current oil supply and demand status, analyzes the development of oil prices and gives insight to the Peak Oil Theory. Energy security, shifts in the geopolitical balance and alternative energy forms are also described. Furthermore, it demonstrates the interdependencies between global trade and transport as well as their dependence on oil. For the transportation segment, it analyzes the four major segments Sea&Ocean, Airfreight, Rail and Road[1] transport taking into account the impact of high oil prices.

Global trade is critical to global business. Volatility/high oil prices have a sustainable impact on the vulnerability and the financial viability on companies involved in global trade. The intention of the thesis is to find indicators, by what extent the transport sector is affected by a high oil prices and how high oil prices shifts market shares within the respective transportation segments.

This leads to the following research questions:

- What role does oil play in today's economy and who are the actors shaping the oil industry?
- What is the past and future oil supply and demand status and what is the Peak Oil Theory?

[1] Sea&Ocean, Airfreight, Rail and Road are simplified terms used to describe various transportation modes, and are therefore capitalized.

- To what extent is globalization driven by the interdependencies of global trade, transport and oil?
- What are the impacts of high oil prices on energy security, geopolitical shifts and economies?
- How will the future of transportation be shaped by high oil prices and alternative energy forms, especially in the four major segments Sea&Ocean, Airfreight, Rail and Road transportation?

1.3 Research Method and Theory

In order to answer the research question adequately, qualitative research methods will be used. The collection of data and the respective assessments are mostly based on neo-institutionalism theory as well on the systematic Grounded Theory. This approach corresponds most closely with the method of hermeneutics.

The neo-institutionalism theory deals with the influence of institutions on human behavior through rules, norms and other frameworks. In this work it is about the role of oil represented by institutions OPEC and IEA, and how people interact and behave within this oil market system. Furthermore, new institutionalism suggests that individuals make certain choices because they can conceive no alternative. The people and companies have shaped globalization and thus also global trade, and they follow the routines because they are taken for granted as “the way we do these things”.

Grounded theory method is a research method to formulate hypotheses based on conceptual ideas using empirical research. Rather than beginning with a hypothesis, the first step is data collection. It includes inductive and deductive thinking to illustrate concepts. This master thesis is applying this concept and is using inductive thinking to determine the future of transport, trade and oil.

1.4 Structure

After the introduction presented in chapter 1, chapter 2 focuses on the role of oil and the Peak Oil Theory. It delivers important information about oil demand and consumption, energy security and the most influential organizations OPEC and IEA. Furthermore, the oil price development is analyzed and the Peak Oil Theory is

discussed. In conjunction with the calculation of oil reserves, the background of unreliable data is also described.
Chapter 3 shows the importance of global trade in our current economic situation and explains the interdependencies between global trade, transport and oil and their relation to today's globalization. It focuses on the different transportation modes Sea&Ocean, Airfreight, Rail and Road and gives insight to their global role and their economic impact.

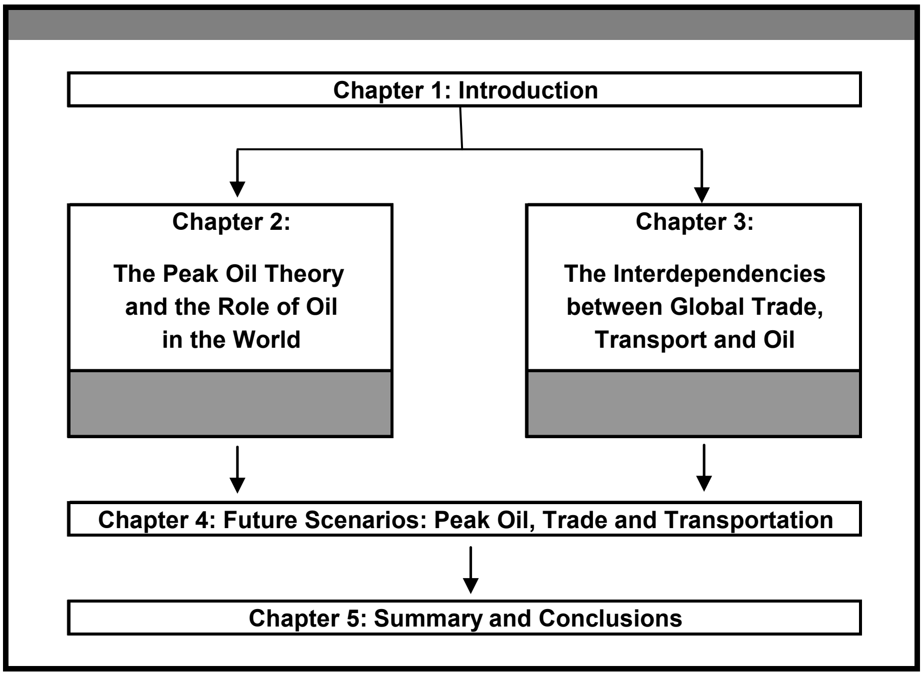

Figure 1.1: Thesis Structure

In chapter 4 future scenarios are discussed. First, it tries to find an answer when Peak Oil will occur and explains the implications of high oil prices to energy security and the geopolitical balance. The economic impacts of high oil prices are presented in three different scenarios. Furthermore, this chapter deals with the transportation impacts and gives an overview of possible oil substitutes, i.e. alternative energy forms. Finally, it will show how the respective transport modes will develop with regard to high oil prices.

2 The Peak Oil Theory and the Role of Oil in the World

" ... (we) cannot afford to bet our long-term prosperity, our long-term security, on a resource that will eventually run out."

- President Barack Obama, 30 March 2011[2] –

2.1 Energy and Fossil Resources

2.1.1 Primary Energy Resources

Energy is at the heart of life. Our mankind relies heavily on energy and it is critical to our daily lives. We take energy for granted, but we sometimes forget that energy not only consists of renewable, but mainly of non-renewable sources.

Non-renewable sources are:[3]

- Fossil fuels: oil, coal & gas
- Mineral fuels: uranium

Renewable sources are:

- Solar energy
- Wind energy
- Tidal energy
- Biomass and
- Geothermal energy

All this forms of energy are called primary energy. Hence, primary energy is an energy form found in nature that has not been subject to any conversion or transformation process. It is energy contained in raw fuels, and other forms of energy received as input to a system.[4]

In 2010, world energy grew over 5%, but we can see two converging trends. Industrialized countries, which experienced sharp decreases in energy demand in 2009 are on the way back to recovery, almost hitting historical trends. Oil, gas, coal, and electricity markets followed the same trend. On the other hand China and India continue their intense demand for all forms of energy.[5]

[2] Obama, B.: Speech at Georgetown University, 2011
[3] Kydes, A.: Primary Energy, 2011
[4] Walser, M.: Renewable Energy, 2011
[5] Enerdata - Global Energy Intelligence: World energy use in 2010: over 5% growth, 2011, p.1

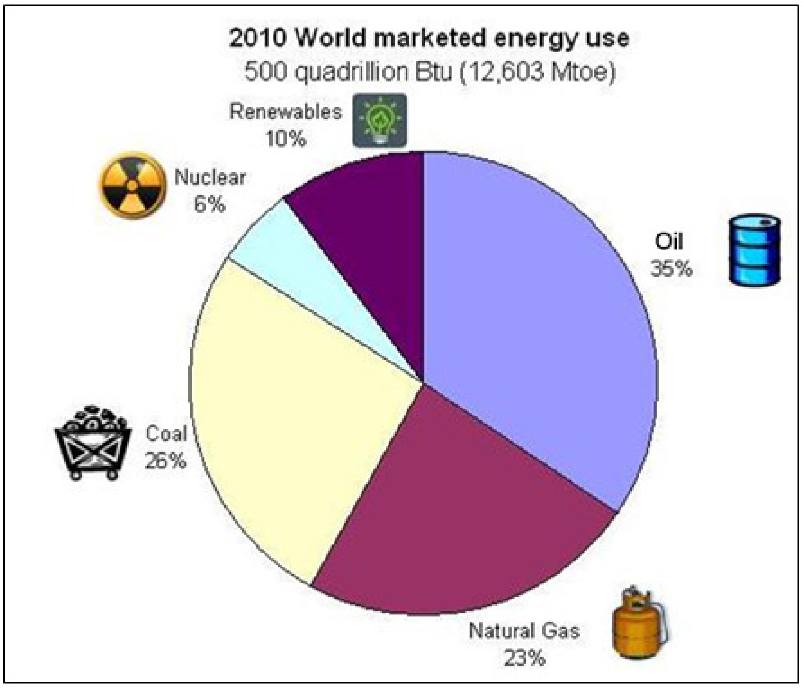

Figure 2.1: 2010 World Market Energy Use, Source: US Energy Information Administration, Report DIO/EIA-0484/2010, 2010

Still, oil is the most important source of primary energy in the world, accounting for about 35% of the total; the other two main fossil fuels, coal and natural gas, account for 26% and 23%, respectively. Nuclear power has a share of 6%. Renewable sources of energy are in a rapid growth phase (currently ca. 10%), but they still account for only a small fraction of primary energy supply.[6] Oil and coal combined represented over 60% of the world energy supply in 2010.

2.1.2 The Role of Oil

Oil has a special role in today's world - it is much more than a commodity. In the developed world, the last three centuries showed large increases in productivity: With the progress in technology, companies and their workforces controlled ever-increasing supplies of cheap energy with ever-greater efficiency. Hence, technology is the enabler, but oil does the work.[7] In short, oil is:

- the densest, portable form of energy known to man[8],
- the current basis of economic wealth and
- the factor of productivity underlying economic growth.

Oil has unique physical properties and it is hard to find anything in the industrial world that does not depend on cheap oil. Rapid substitution is difficult and oil extracted

[6] International Monetary Fund (IMF): World Economic Outlook, 2011, p. 92
[7] Odland, S.: Strategic Choices, 2006, p. 5-7
[8] While uranium atoms have a higher energy density, they are neither easily transported nor used.

from the ground is neither depreciated nor replaced. Today's global economy – especially production and distribution - is built around cheap transportation for just-in-time manufacturing and inventory management. [9]

Oil has the principal attribute to do work and its energy replaces labour formerly provided by traction animals or people. Accordingly, oil could be considered a form of labour, as Rep. Bartlett describes it:

> "One barrel of oil, 42 gallons of oil, equals the productivity of 25,000 man-hours. That is the equivalent of having 60 dedicated servants that do nothing but work for someone. We can get a little better real-life example of this. A gallon of gas will drive a 3-ton SUV...20 miles at 60 miles an hour down the road. That is just one little gallon of gas, which, by the way, is still cheaper than water."[10]

2.1.3 Oil and the Energy Security Dimension

The importance of oil for global economy can not be denied, but oil is also strategically important. It is from utmost interest of international states and institutions and plays a huge role in achieving policy and strategic resources goals. It is hard to evaluate the risks and potential challenges when Peak Oil occurs. [11]

In order to understand the meaning of energy security, we need to clarify what energy security is.

Energy security is the availability of sufficient supplies at affordable prices. But there are four dimensions: [12]

1. Physical security: protecting the assets, infrastructure, supply chains and trade routes including providing quick replacements and substitutions
2. Access to energy: critical point which means to develop and acquire energy supplies (physically, contractually, commercially)

[9] Odland, S.: Strategic Choices, 2006, p. 5-7
[10] Bartlett, R.: The Fourth Special Order speech on Peak Oil to the US Congress, 2005
[11] Zentrum für Transformation der Bundeswehr: Peak Oil, p. 8
[12] Yergin, D.: The Quest, 2011, p. 266-267

3. Energy security as a system: national policies and international organisations to respond in a coordinated way to disruptions, dislocations, etc.
4. Investment: policies, which promote investment and development to ensure that adequate supplies and infrastructure will be available

Oil-importing countries think in terms of security of supply. Oil-exporting countries turn the question around. Their "security of demand" generates economic growth and revenues in order to maintain stability.[13]

Energy security may seem like an abstract concern – certainly important, but hard to pin down. But disruption and turmoil – and the evident risk – demonstrate both its tangibility and how fundamental it is to modern life.[14]

Energy security is not a new idea. In 1911 Winston Churchill decided to convert the battleships of the Royal navy from coal to oil. Oil would make the ships faster and more flexible than those of the Germans. But Britain had no oil resources, so oil had to be bought from Persia, which was risky because Persia was insecure and the way was long and risky. Churchill responded with what would become a fundamental touchstone of energy security: diversification of supply. "On no one quality, no one process, on no one country, on no one route, and on no one field must we be dependent. Safety and certainty in oil lie in variety and variety alone."[15]

The United States, the biggest consumer of energy, often uses the term of energy independence. In 1973, President Nixon was the first one, who used this in his "Project Independence Speech" due to the embargo of Arab oil exporters in response to the US resupply of weapons to Israel.[16] The oil shock was hardly limited to the US. The embargo created shortages and economic disarray around the world, generating a mad scramble for oil among companies, traders and countries. It means a massive shift in the global political and economic balance of power away from importing countries to the exporters.[17] The phrase of "energy independence" has remained a part of the political vocabulary ever since. Every president has evoked energy

[13] Yergin, D.: The Quest, 2011, p. 266-267
[14] Ibid, p. 264
[15] Ibid, p. 265
[16] Ibid, p. 267
[17] Ibid, p. 269

independence as a prime objective. From being the number one oil exporter, the US. imports now more than 50% of oil.

2.1.4 Excurse: Oil Types

This section is supposed to give a rough overview about the different oil types and their accessibility: [18]

a) **Conventional oil:** generally refers to easily accessible and conveyable oil. It is the preferred crude oil, also called "sweet" and "light", because it can easily be refined into the most desired products, like gasoline and diesel. Conventional oil reserves are conveyed by self-pressure pumping, flooding with water or injecting water or gas. About 95% of total oil production comes from conventional oil reserves.

b) **Non-conventional oil:** technically, non-conventional oil is more complicated and more expensive to convey. The term non-conventional refers to the geological aspect of the formation and characteristics of the deposits but also to the technical necessity of an ecologically acceptable use.

- **Oil shale:** is an oil-and-bitumen-saturated sedimentary rock, in which no conversion into crude oil has taken place. The liquefaction is performed by mining, crushing and heating. The net energy yield is rather low and the environmental performance is seen as poor.
- **Oil sands (tar sands):** is sandstone with a fraction of viscous heavy and extra heavy oils, which are mined by open pit and can be liquefied by reducing, heating and separation. The conveying is very expensive, but with a better energy balance than oil shale.
- **Heavy crude oil:** requires special refining equipment to process the impurities. Large amounts of hydrogen must be added to heavy oil at the refinery to create the desired outputs of lighter hydrocarbon products. The production rate is comparatively low. However, this stems from technological constraints and not from the amount of accessible resources. Most current refineries are not equipped

[18] Zentrum für Transformation der Bundeswehr: Peak Oil: Sicherheitspolitische Implikationen knapper Ressourcen, 2010, S. 89

to handle sour, heavy oil. For instance: the "extra" oil Saudi Arabia offered to provide after Hurricanes Rita and Katrina was spurned by the market.[19]

- **Deepwater oil:** refers to oil resources under water as of 500m water depth. The conveying is technically very difficult and expensive.
- **Polar oil:** refers to the oil reserves in the Arctic Circle. It is conveyed primarily in Alaska and Siberia, and requires technically complex and costly methods.

2.2 Oil Consumption – The Demand Side

2.2.1 Consumption Facts and Trends

The following graphs and explanations will give a global overview about the trends since 1980 as well as the geographical locations of oil consumption.

According to the BP Statistical Review of World Energy 2011, oil consumption is constantly rising worldwide (s. Fig. 4). In 2010, 87 million barrels per day (mb/d) have been consumed.[20] To date, the vast majority of world demand for oil has come from the member countries of the Organization for Economic Co-operation and Development (OECD) countries (the so-called 'Western world'). But, in future, the principal growth in demand will come from the non-OECD countries (the so-called 'developing world').

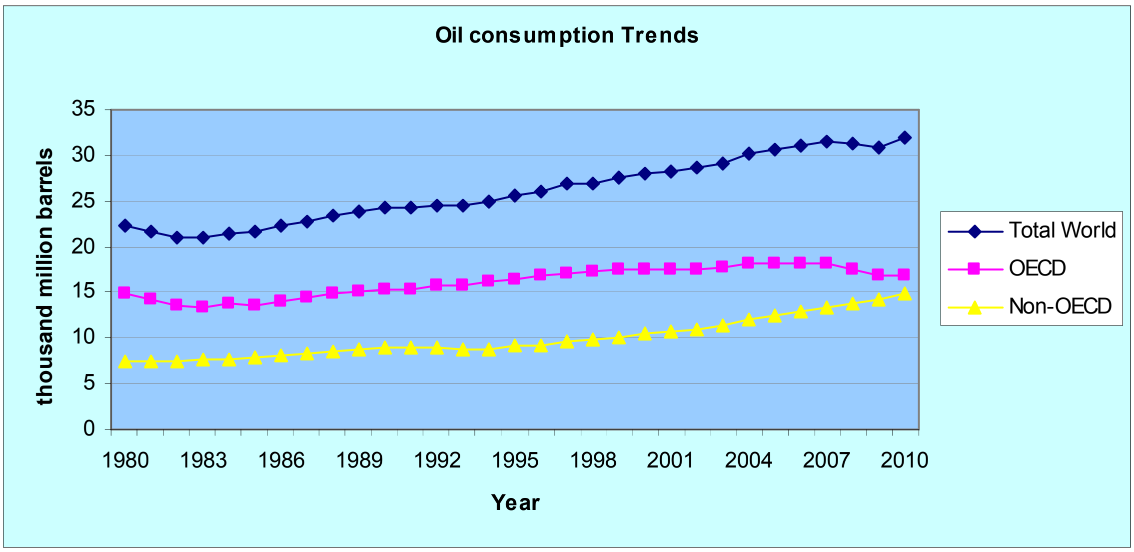

Figure 2.2: Yearly consumption of oil worldwide. Source: Data from BP Statistical Review World Energy 2011, own illustration

[19] Odland, S.: Strategic Choices for Managing the Transition from Peak Oil to a reduced petroleum economy, 2006, p. 24
[20] BP Statistical Review of World Energy 2011

The non-OECD countries comprise the vast majority of the world's population (some 5 billion people of the world's current population of 6 billion), so the consequences of a steady growth in per capita oil-demand in these nations need no further elaboration.[21]

Figure 2.2 shows the oil consumption per thousand barrels a day per country. The US is the major contributor of the worldwide oil consumption with 21% in 2010.

The industrialized countries are the largest consumers of oil but have not been the most important growth markets for some years. The OECD-Countries, for instance, account for more than 50% of worldwide daily oil consumption. In contrast, however, oil demand in the OECD fell by 4% over the 2000-2010 periods, while demand outside the OECD grew by 44%.

2.2.2 Excurse: International Energy Agency (IEA)

In face of the oil embargo in 1973, the Western alliances hold the Washington energy conference, out of which the International Treaty of 1974 emerged. The treaty established the International Energy Agency (IEA). It outlined a new energy security system that was meant to deal with disruptions, cope with crises, and avert future bruising competition that could destroy an alliance.

In the 1970s, the major oil exporting countries took control of the world market through OPEC, which represents key-oil exporting countries. Hence, the IEA was used as a deterrent against the future use of an oil weapon by exporters: the IEA was founded to represent importing countries to counterbalance OPEC.

Currently, the IEA numbers 28 industrial countries as members and provides monitoring and analysis of energy markets, policies and research. One of the core responsibilities is to coordinate the emergency sharing of supplies in the event of a loss of supplies. Each member is meant to hold strategic oil stockpiles, which can be released on a coordinated basis in an event of disruption.

Currently, IEA nations have 1.5 billion barrels of public stocks, 700 million barrels in the US alone. To put this in perspective: When Iranian exports disappear, the 1.5 billion could compensate for the shortfall for more than 2 years. The IEA stocks are nothing but a giant insurance policy. Since the establishment of this process, IEA

[21] Industry Task Force on Peak Oil & Energy Security: The Oil Crunch, 2010, p. 13

members have only three times triggered an actual emergency drawdown of these strategic stockpiles. During the Golf crisis 1990-1991, in 2005 because of Hurricane Katrina and in 2011 in response to the persisting loss of supply from the Libyan civil war.
The IEA has evolved, shifting away from confrontation in the 1970s to promoting dialogue between consuming and exporting countries, also non-IEA and non-OPEC countries. One of the initiatives of these dialogues is JODI: Joint Oil Data Initiative. Its objective is to provide a more complete and transparent view of supply and demand, where both IEA and OPEC are members. Of course this framework has its limits, because it depends on the relationships not among blocs but among specific nations and how they see their interests and the degree to which they can act upon those interests.[22] And neither China nor India are members of the IEA, but given their growing scale and their importance, their participation is essential for the system to work more effectively.[23]

2.2.3 Oil consumption per country and capita

In developed economies, oil is used much more intensively than in developing economies. Canada and the United States have the highest consumption of oil per capita, mainly due to the dependence of private vehicles to travel relatively long distances.

[22] Yergin, D.: The Quest, 2011, p. 270-275
[23] Ibid, p. 280

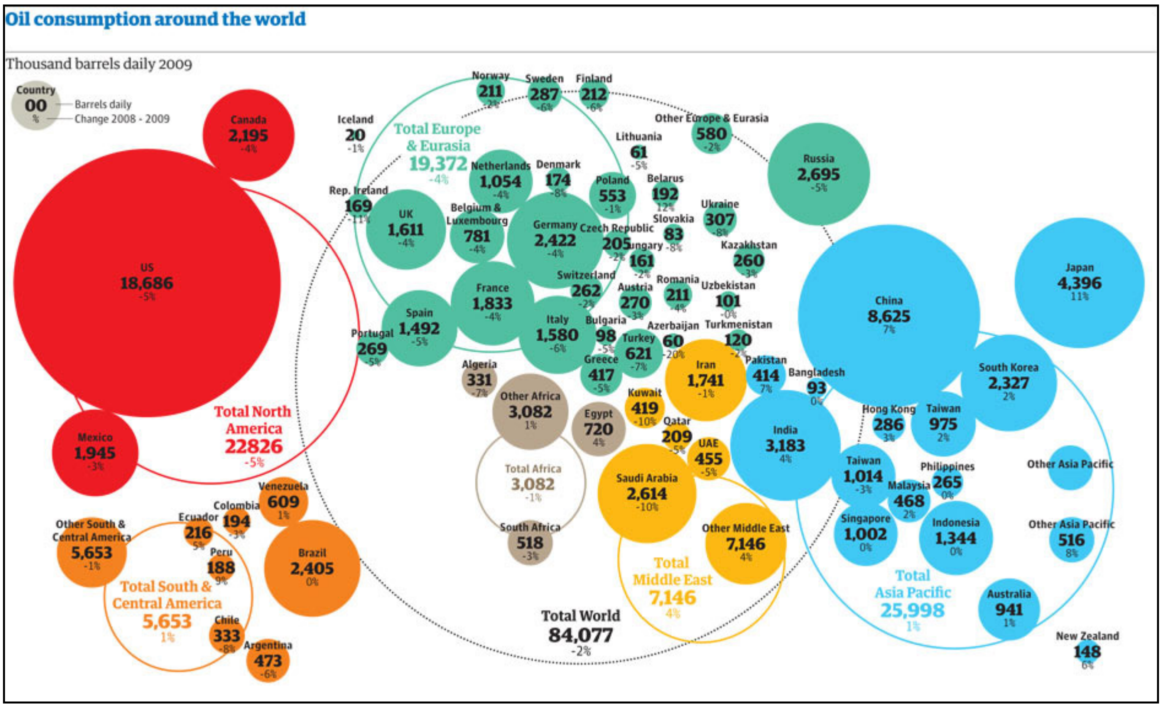

Figure 2.3: Oil consumption around the world in 2009. Data from BP Statistical Review of World Energy 2010.

To put this in perspective, oil consumption in the United States and Canada equals almost 3 gallons per day per capita, while oil consumption in the rest of the OECD equals 1.4 gallons per day per capita. Outside of the OECD, oil consumption equals 0.2 gallons per day per capita.[24]

Regionally, the largest consuming area remains North America (dominated by the United States), followed by Asia (with Japan being the largest consumer), Europe (where consumption is more evenly spread among the countries), and then the other regions (see figure 2.4). Asia is the region with the fastest demand growth.

Oil Consumption by Region:

Country	%
US	21%
Canada	3%
Mexiko	2%
Total North America	**26%**
China	11%
Japan	5%
India	4%
Other Asia Pacific	12%
Total Asia Pacific	**31%**
Russia	4%
Germany	3%
France	2%
Other Europe & Eurasia	14%
Total Europe & Eurasia	**23%**
Total Middle East	**9%**
Total S. & Cent. America	**7%**
Total Africa	**4%**
Total World	**100%**

Figure 2.4: Percentage of total oil consumption by country in 2010. Data from BP Statistical Review of World Energy 2011.

[24] U.S. Energy Information Administration (EIA): Oil Market Basics, Chapter Demand, 2012

2.3 Oil resources – The Supply Side

2.3.1 Where Oil comes from

The vast majority of oil is restricted to a limited number of geologically predictable places on earth. Sedimentary basins along the current or former edges of continents like river deltas, continental margins, deserts and arctic areas are the four present-day locations most likely to hold oil or gas deposits beneath them. The main source of oil production is found in the Middle East in the "Oil Triangle" of Saudi Arabia, Kuwait, Iraq and Iran.

Besides North America, where oil is concentrated in the Gulf of Mexico and in basins along the edge of the Rocky Mountains, Russia, the Caspian Sea and the Atlantic continental margins of Africa and South America are the other significant oil-prone areas. 47%, almost half of the world's resources come from relatively few giant oil fields. Each of these fields produces at least 100.000 barrels/day. To put this into perspective, the world consumes more than 100.000 barrels of oil every 7 minutes.[25]

Among the few giant oil fields, four aging 'supergiant' fields together produce around 8 million barrels per day, which equals about 10% of the world's daily production. 4.000 smaller fields are responsible for the remaining 53% of oil production. Since oil is only available in a few places, trade has evolved to export oil from producing to consuming countries. Figure 2.5 shows the most significant oil import/export relationships in 2010, based on volume. The Middle East was the biggest exporter with a share of 35% of worldwide oil exports in 2010.[26] These trade dependencies are a major factor shaping the geopolitical landscape.[27]

2.3.2 Excurse: OPEC

The Organization of the Petroleum Exporting Countries (OPEC) is one of most influential organisations with regard to oil. The founding members of the organization were Iran, Iraq, Kuwait, Saudi Arabia and Venezuela, but were later joined by Qatar, Indonesia, Libya, United Arab Emirates, Algeria and Nigeria.

25 Odland, S.: Strategic Choices, 2006, p. 19
26 BP Statistical Review of World Energy 2011, p. 18
27 Odland, S.: Strategic Choices, 2006, p. 19

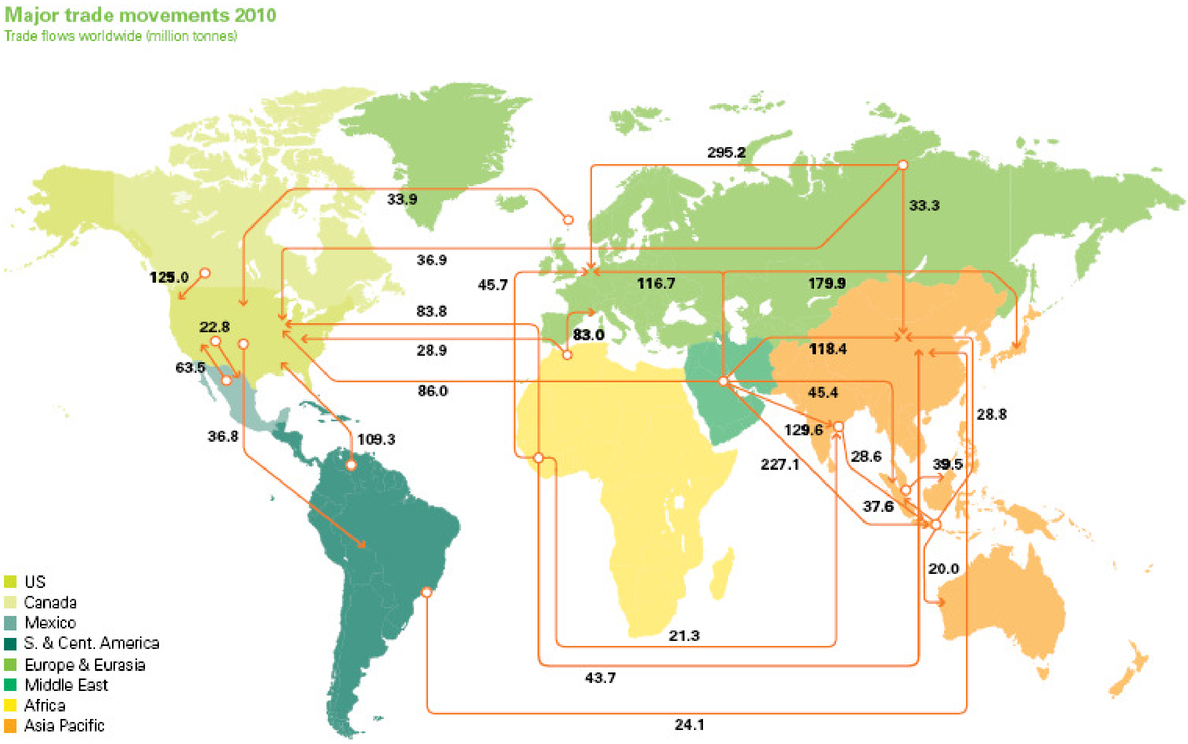

Figure 2.5: Major trade flows of oil from producing to consuming countries, source: BP Statistical Review of World Energy 2011, p. 19

The purpose of OPEC is the stabilization of oil prices in international oil markets, the minimization of fluctuations and provision of efficient and regular supply to oil consumer nations. In its own interest, OPEC is also obliged to secure a steady income to the producing countries[28], which means to keep prices at a high level.[29] Since OPEC holds 77% of world crude oil reserves and 44% of the world's crude oil production, it has considerable control over the global market and oil prices.[30] Nevertheless, due to the subsequent discovery and development of large oil reserves in Alaska, the North Sea, Canada, the Gulf of Mexico, the opening up of Russia, and market modernization, OPEC ability to control the price of oil has diminished.[31]

2.3.3 Oil reserves data and calculation

According to BP Statistical Review[32], there are 1383 thousand millions barrels of proved reserves. Taking into account current daily consumption of 87 million barrels per day (which equals ca. 32 thousand million barrels per year), world reserves in

[28] OPEC: OPEC Statute, Chapter 1, Articel 2, 2008
[29] Duarte, E.: OPEC, 2012
[30] Turquoise Partners: Iran Investment, 2010, p. 7
[31] OPEC: OPEC Statute, Chapter 1, Articel 2, 2008
[32] British Petroleum: BP Statistical Review of World Energy 2011

2010 were sufficient to meet ca. 46 years of global production respectively consumption based on today's numbers.

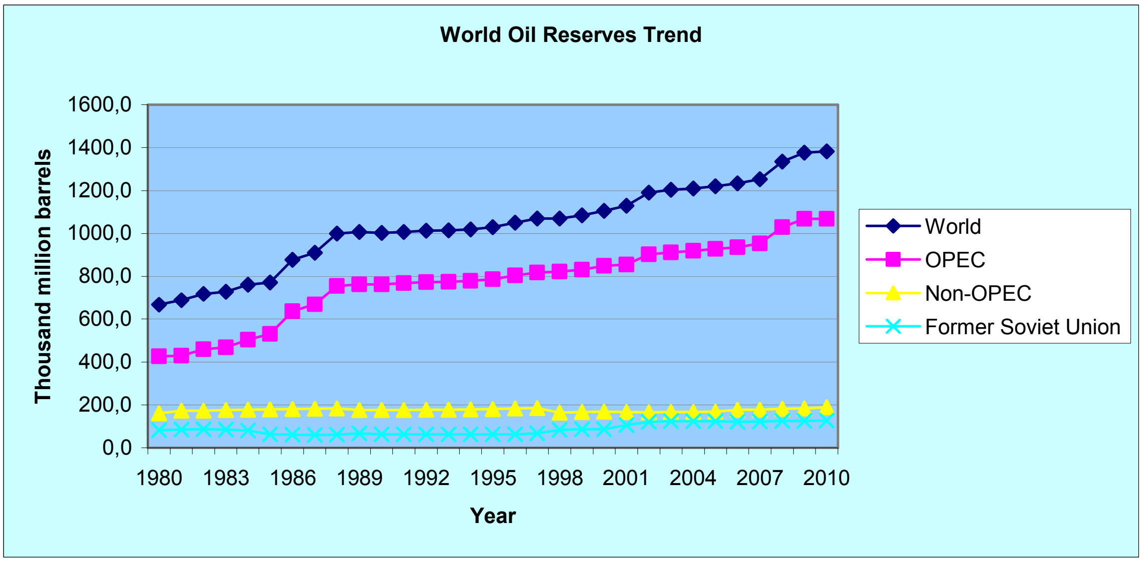

Figure 2.6: World Oil Reserves, source: BP Annual Statistics, 2011, own illustration

As already mentioned ca. 77% of the officially reported reserves in the world are located in OPEC countries (Figure 2.7). More than half of that – some 37% of the remaining reported oil in the world - is located in Saudi Arabia, Iraq and Iran. After the Middle East, Venezuela (15%) and Russia (6%) are reporting the largest percentage of the total reserves. The U.S. and its two largest suppliers – Canada and Mexico – have only 5% of the world's reserves.[33]

When it comes to oil reserves reporting, most of the western world reports their reserves as P2 (probability 50%) based on the following definitions:[34]

Proven (P1 or P-90) Reserves have a 90% certainty of existing and being producible at today's prices using existing technologies.

Probable (P2 or P-50) Reserves have a 50% probability of existing and being economic at today's prices using existing technologies.

Possible (P3 or P-10) Reserves are hypothetical to speculative with only a 10% chance of existing or being economic.

[33] Odland, S.: Strategic Choices, 2006, p. 33
[34] Ibid, p. 33

Oil: Proved reserves at end 2010	Thousand million barrels	Share of total	R/P ratio
Saudi Arabia	264,5	19,1%	72,4
Venezuela	211,2	15,3%	more than 100 years
Iran	137,0	9,9%	88,4
Iraq	115,0	8,3%	more than 100 years
Kuwait	101,5	7,3%	more than 100 years
United Arab Emirates	97,8	7,1%	94,1
Russian Federation	77,4	5,6%	20,6
Libya	46,4	3,4%	76,7
Kazakhstan	39,8	2,9%	62,1
Nigeria	37,2	2,7%	42,4
Canada	32,1	2,3%	26,3
US	30,9	2,2%	11,3
Qatar	25,9	1,9%	45,2
China	14,8	1,1%	9,9
Brazil	14,2	1,0%	18,3
Angola	13,5	1,0%	20,0
Algeria	12,2	0,9%	18,5
Mexico	11,4	0,8%	10,6
India	9,0	0,7%	30,0
Azerbaijan	7,0	0,5%	18,5
Rest of World	84,3	6,1%	
Total World	**1383,2**	**100,0%**	**46,2**
of which: OECD	91,4	6,6%	13,5
OPEC	1068,4	77,2%	85,3
Non-OPEC £	188,7	13,6%	15,1
European Union #	6,3	0,5%	8,8
Former Soviet Union	126,1	9,1%	25,6

Figure 2.7: Countries with the largest Reported Oil Reserves, Source: BP Annual Statistics, 2011

The issue with reserve reporting is that reserves are not static. What needs to be considered on the one hand is the difference between reserves and additions. The difference is substantial, because with better knowledge of the field, the field develops and reserves and production are often increased. To put this in perspective, 86% of oil reserves in the US are the result of not what is estimated at time of discovery but of revisions and additions that come with further development, according to a study by the US Geological Survey. Accordingly, much more oil is discovered by the petroleum engineers, developing and expanding the fields than by explorers, who found the field.[35]

On the other hand, if prices rise, some reserves that were previously sub-economic will be reclassified as proven or probable. [36]

2.3.4 Criticism on OPEC oil reserves reporting

The main problem with oil reserve accounting is the lack of standardization - from company to company and from country to country, which makes summing up individual country reserves result in unrepresentative totals. Moreover, countries

[35] Yergin, D.: The Quest, 2011, p. 238
[36] Odland, S.: Strategic Choices, 2006, p. 33

changed what they report as oil: only ‘conventional’ oil including the coveted ‘light, sweet crude’ and the less favored ‘heavy, sour crude’ was formerly reported. Now, the reports also include “non-conventional” oil, which encompasses not only deep-water oil and polar oil, but also oil synthesized from ‘oil sands’ and ‘oil shale’s’.
This could lead to the impression that oil reserves of conventional oil are growing with the same energy return per investment and the production can be kept at the same rate as with conventional oil.[37]

Although the US and Russia have different reporting numbers, both states report P1, P2 and P3 numbers, respectively. In the United States, the Securities and Exchange Commission (SEC) allows companies to count as reserves only oil that is under current development, and for which extraction funds have been committed. [38]

Especially OPEC countries do not follow the official classification scheme. In 1985, in face of an oil glut, OPEC decided to implement a production quota system. Each member’s allowable production was based on their share of total OPEC reserves, i.e. the higher the national reserves, the higher the production quota and thus the country’s export profit.[39]
This resulted in a sudden reporting of additional 30 billion barrels in tiny Kuwait in 1985. Other countries followed and the reserves of Iraq, Iran, Venezuela and United Arab Emirates jumped inexplicably, yet there were no reported new discoveries or advances in technology (e.g. Saudi-Arabia booked an additional 90 billion barrels).[40]
All in all, more than 300 billion barrels of oil were added to the official supply (see figure 2.8), because each state wanted to have high production rates at a high price.

[37] Odland, S.: Strategic Choices, 2006, p. 33
[38] Ibid, p. 33
[39] Zentrum für Transformation der Bundeswehr: Peak Oil: Sicherheitspolitische Implikationen knapper Ressourcen, 2010, S. 5
[40] Odland, S.: Strategic Choices, 2006, p. 31

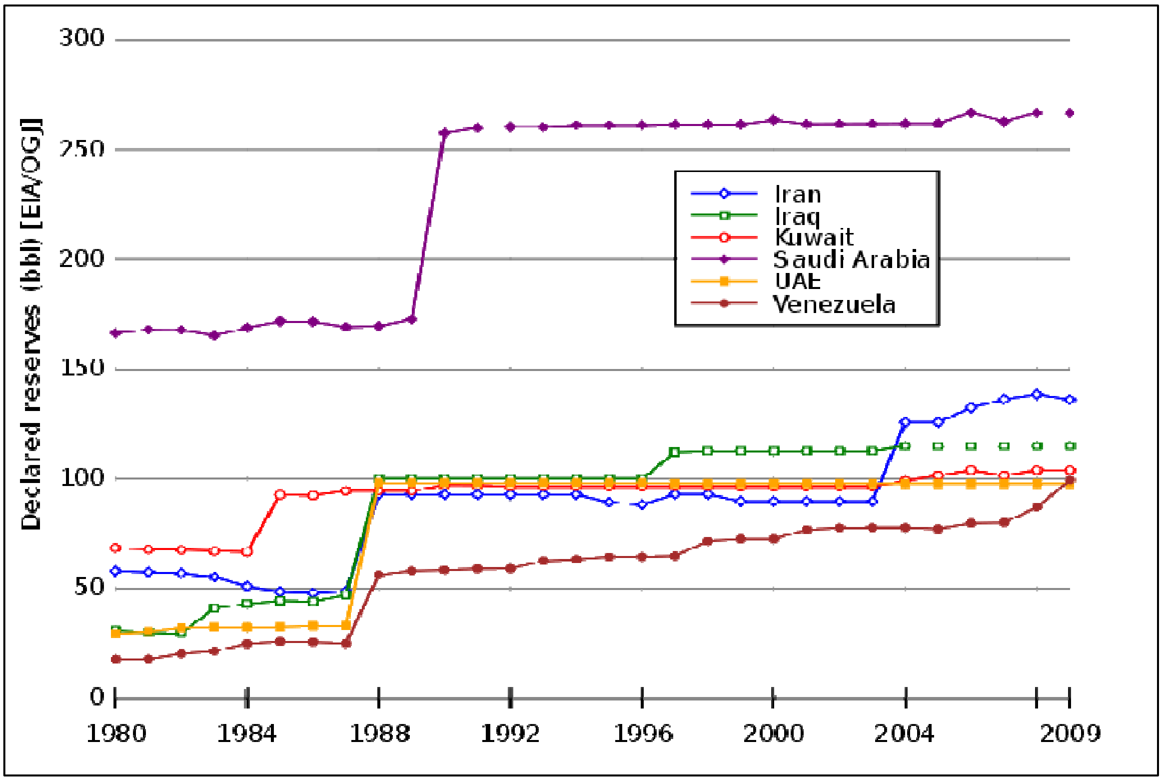

Figure 2.8: OPEC declared reserves between 1980 and 2008. Source: Data from EIA (US Energy Information Administration), International Energy Statistics, Crude Oil Proved Reserves for OPEC (based on Oil & Gas Journal), 2009

It is worth mentioning that most maturity-related declines have emerged in economies that are not members of OPEC, including Russia, but despite the jumps in the 1980s, some OPEC producers reportedly also face challenges from mature fields, including Saudi Arabia.[41]

Due to the lack of transparent oil reserve accounting in OPEC states, the room for interpretation is often used to manipulate the respective reserves. Many analysts doubt the official reporting and believe that the newly reported oil was only “paper reserves” and politically motivated. So far, no verifiable data has been released since the countries nationalized their reserves. It might be possible that the OPEC countries may have switched to reporting their ultimately recoverable reserves instead of remaining reserves. Despite heavy annual production, most OPEC countries reported more or less virtually flat reserves for the following 15 years. Taking all these aspects into account, OPEC’s reserves are probably significantly lower than reported.

[41] International Monetary Fund (IMF): World Economic Outlook, 2011, p. 97

2.4 Development and Effect of Oil Prices

2.4.1 Development of Oil Prices

Understanding the oil price development and predicting oil prices is a complex issue. The usual intention of prices is to indicate scarcity or abundance.[42] Activity goes hand in hand with in- or decreasing prices and usually higher prices stimulate innovation and encourage people to figure out new ways to increase supply.[43] For oil, the market price should reflect the opportunity cost of bringing an additional barrel of oil to market including compensating for the cost of extraction as well as the cost relative to expected future scarcity.

The following table (see figure 2.9) shows the development of oil prices from 1970 to 2011. The first oil shock was the OPEC oil embargo, which led to a price increase of 135% at that time. The second oil shock was the Iranian revolution and the Iraq-Iran war, which resulted in a further price increase of ca. 150%. As mentioned in figure 2.9, point (A) refers to oil counter shock, also known as the OPEC oversupply, which led to price decrease of 64%. The first gulf war is also worth mentioning (1), leading to a price increase of 73% and the World Trade Center attack on September 2011 (C), and lowering prices by almost 30%. The Third Oil Shock stemmed from rising demand, fear of peak oil and monetary debasement, bringing prices up to almost 134$/barrel, but the financial crisis reduced prices again by almost 71% (D).

Considering these aspects and the above described development of oil prices, the basic price principle would apply to many other realms but not in terms of oil. When it comes to high oil prices in practice, several factors need to be considered: it is important to distinguish between scarcity and other reasons for high oil prices.[44]

[42] International Monetary Fund (IMF): World Economic Outlook, 2011, p. 95
[43] Yergin, D.: The Quest, 2011, p. 236-237
[44] Auckland Regional Council: Price Forecasts for Transport Fuels, 2009, p. 6-7

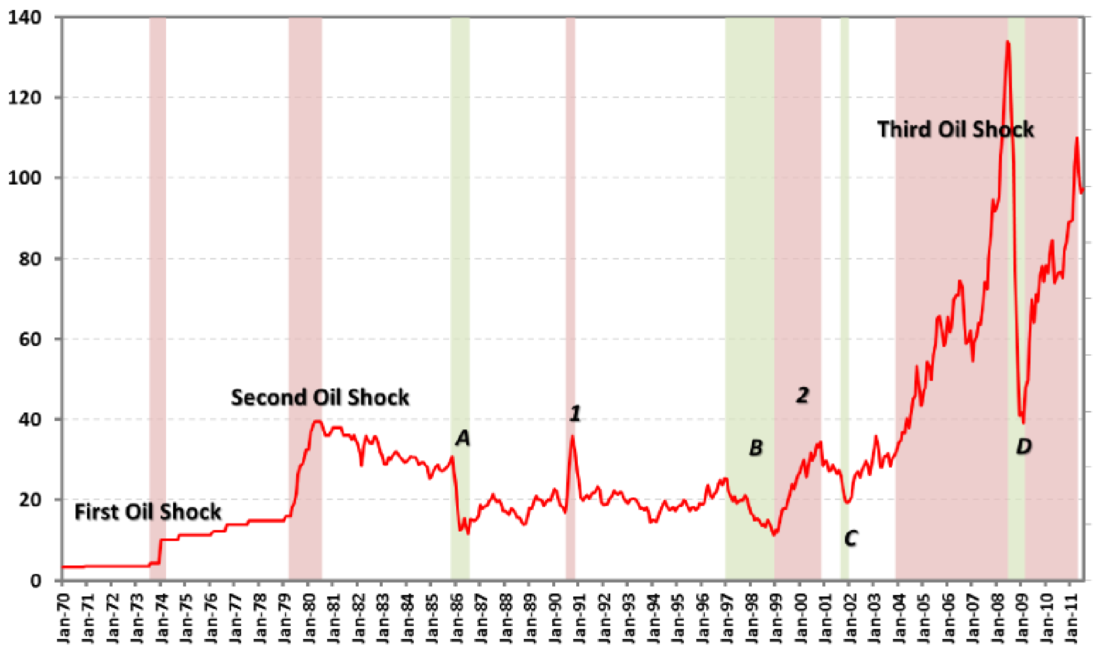

Figure 2.9: West Texas Intermediate, Monthly Nominal Spot Oil Price (1970-2011), Source: Federal Reserve Bank of St. Louis, 2011

The physical sides of demand and supply, financial factors as well as various reasons such as oil shocks, etc. are building a complex model for oil price development: [45]

- Physical: in recent years supply had difficulties to keep up with demand, which means declining oil availability. This results in a physical inability to provide a higher level of supply and reflects technological and geological constraints. [46]
- Financials: the interaction between cyclical financial factors and price elasticises of demand and supply can lead to fluctuations in oil prices. Moreover, high oil prices are the result of the systematic inflation of most currencies through money supply. So, monetary policies followed by most central banks and governments guarantee higher nominal energy prices, particularly if measured in US dollars.[47]
- Other: oil shocks, oversupply or a recession can influence the market price of oil. It may also be subject to “super-cycles” caused by long implementation lags for discovery, exploration and capital investments. Usually, these types tend to occur suddenly.

[45] Auckland Regional Council: Price Forecasts for Transport Fuels, 2009, p. 58-59
[46] International Monetary Fund (IMF): World Economic Outlook, 2011, p. 95
[47] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 262

Accordingly, oil price forecasts are still uncertain. Although newer forecasts try to integrate the complicated models of reserve, discovery and depletion, there is little consensus among forecasters. The range of oil prices in 2028 varied in their predictions from a low of $70 USD/barrel to a high of $220 USD/barrel.[48]
Other models expect an average price of oil at ca. $120 to plateau from 2008-2020, followed by a sharp increase up to ca. $400 USD per barrel by 2060. These variances reflect the volatile nature of oil prices, caused by low supply and demand elasticities.[49]

2.4.2 Oil Price Elasticities: 1990-2009

Price elasticities show the responsiveness i.e. the elasticity of changes in supply and/or demand to a change in its price. To calculate oil price elasticities, two things need to be considered: [50]

a) Oil can hardly be substituted due to its unique physical properties
b) But: if oil can be replaced by natural or synthetic substitutes, even small oil price increases may lead to demand of these substitutes

The IMF conducted a price and income elasticity model calculation for short and long-term oil demand in OECD and Non-OECD countries (see figure 2.10). This should reflect the difference between almost saturated and emerging markets. Firstly, the market model includes the underlying drivers such as resource availability, production capacity, and demand growth. Secondly, among other factors, calculations on long-term oil price developments ignore short-term fluctuations and exclude all price fluctuations with a cycle period of less than nine years.[51]

Price Elasticity:

Combined results for OECD and Non-OECD countries are showing very low short-term price elasticity, about –0.02, which means a 10% increase in oil prices leads to a reduction in oil demand of only 0.2%. Long-term price elasticity is at – 0.072, which means a 10% permanent increase in oil prices reduces oil demand by only about 0.72% after 20 years.

[48] Auckland Regional Council: Price Forecasts for Transport Fuels, 2009, p. 58-59
[49] Ibid, p. 6-7
[50] International Monetary Fund (IMF): World Economic Outlook, 2011, p. 91
[51] Ibid, p. 91

Non-OCED countries show a much lower price elasticity than OECD countries, which reflects the decreasing demand of oil in the OECD countries and the growing importance of other energy sources. Overall, the numbers are very small and show a surprisingly low price responsiveness to oil consumption. [52]

Income Elasticity:

The growing importance of emerging market economies appears to have reduced world oil demand price elasticity (in absolute terms) and increased income elasticity. Combined results are showing short-term income elasticity at 0.68, which means that a 1% increase in income is linked to an increase in oil demand of 0.68%. The long-term elasticity is considerably smaller, at 0.29. This result indicates that oil consumption has been (slowly) substituting away from oil. In fact, the share of oil in total primary energy consumption has been decreasing since 1980. It is worth mentioning is the fact that income elasticity is higher in the short term than in the long term, which suggests that the response of oil consumption to an income shock involves some cyclical overshooting. [53]

Short-term income elasticity for Non-OECD is only slightly higher than for OECD countries; however, long-term income elasticity is significantly higher for emerging market economies, at 0.39, but shows only a combined elasticity of 0.29 for OECD and Non-OCED countries. Compared to the value of energy demand, which is almost one, the results suggest that the use of oil has been declining substantially. It indicates that instead of economies becoming more energy efficient, the importance of other energy sources is growing, even in emerging markets.[54]

For the transport sector, the analysis suggests that transport is relatively unresponsive to price signals, in particular to changes in prices of fuels. Moreover, this unresponsiveness indicates that is costly to reduce energy use in transport, relative to other economic activities.[55]

[52] International Monetary Fund (IMF): World Economic Outlook, 2011, p. 91-95
[53] Ibid, p. 91-95
[54] Ibid, p. 95
[55] OECD Joint Transport Research Center: Long Run Trends in Transport Demand, 2007, p. 32

	Short-Term Elasticity		Long-Term Elasticity	
	Price	Income	Price	Income
Combined OECD[1] and Non-OECD	–0.019 [–0.028, –0.009]	0.685 [0.562, 0.808]	–0.072 [–0.113, –0.032]	0.294 [0.128, 0.452]
OECD	–0.025 [–0.035, –0.015]	0.671 [0.548, 0.793]	–0.093 [–0.128, –0.057]	0.243 [0.092, 0.383]
Non-OECD	–0.007 [–0.016, 0.002]	0.711 [0.586, 0.836]	–0.035 [–0.087, 0.013]	0.385 [0.193, 0.577]

Source: IMF staff calculations.

Note: Median elasticities and confidence intervals showing 10th and 90th percentile of the distribution in brackets are estimated by Monte Carlo simulations. Long-term elasticities are calculated using a 20-year horizon.

Figure 2.10: Oil Demand Price and Income Elasticities (1990-2009), Source: IMF staff calculations, World Economic outlook, 2011, p. 97

What needs to be mentioned is the fact, that this analysis represents today's situation and uses historical numbers for calculating the elasticities. Today, securing the access is relatively easy via the world market [56] and the effects on oil prices in the past were more or less muted as oil production largely kept pace with the increase in oil consumption.[57] OPEC is generally cooperative during crises and the interdependence of exporters and importers, coupled with a significant presence of U.S. military in Arab countries, supports - at least economy wise – a good atmosphere. [58]

2.5 The Peak Oil Theory

2.5.1 Definition

Generally, the Peak Oil Theory refers to the maximum rate of oil production and represents the time at which the flow rate of a single oil field or entire region reaching the absolute maximum. [59]

All in all, the whole peak theory is pretty straightforward, arguing that world oil output is currently near the highest level it will ever reach, that about half of the world's resources have been produced, and that the point of imminent decline has already begun, or is soon to set in.[60]

[56] Zentrum für Transformation der Bundeswehr: Peak Oil: Sicherheitspolitische Implikationen knapper Ressourcen, 2010, S. 7

[57] International Monetary Fund: The Impact of Higher Prices on the Global Economy, 2008, p. 3

[58] Zentrum für Transformation der Bundeswehr: Peak Oil: Sicherheitspolitische Implikationen knapper Ressourcen, 2010, S. 7

[59] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 339

[60] Yergin, D.: The Quest, 2011, p. 233

The general rationale for the existence of the Peak Oil is that conventional oil is only available to a limited extent. Due to the fossil nature of oil, it cannot be denied that there is a "depletion point" - at least in production of conventional oil.[61]

2.5.2 Hubbert – The Peak Oil Founder

In 1956, the geophysicist King Hubbert published a theory which is a point of discussion until now. He created a graph of oil production, which takes the shape of a bell curve. Logically, oil production starts at zero and then rises to a peak production. Once peak production has been reached, production declines and prices go up until oil resources are depleted or too costly for a widespread use. [62]

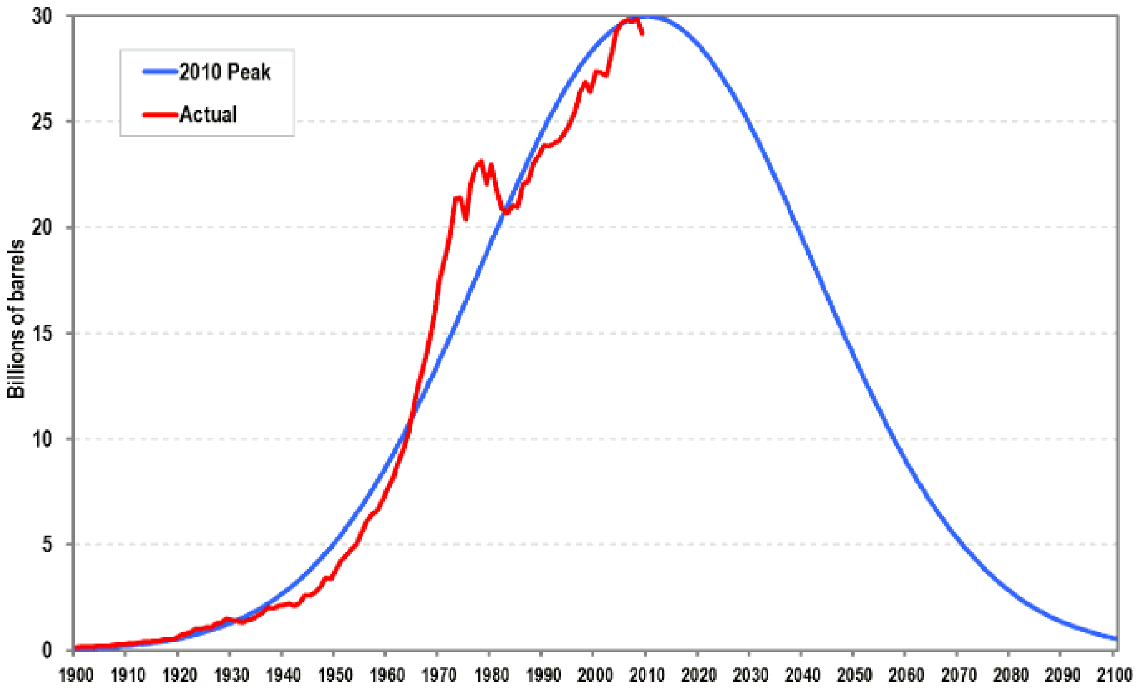

Figure 2.11: World Annual Oil Production (1900-2009) and Peak Oil (2010 Scenario), Source: Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, http://people.hofstra.edu/geotrans/eng/ch5en/appl5en/worldoilreservesevol.html

As geologist Colin Campell states: “It’s quite a simple theory and one that any beer drinker understands. The glass starts full and ends empty and the faster you drink it the quicker it’s gone.”[63]

Hubbert used his model to predict oil production in the United States. According to his calculations, oil production would peak between 1965 and 1970. His findings

[61] Zentrum für Transformation der Bundeswehr: Peak Oil: Sicherheitspolitische Implikationen knapper Ressourcen, S. 83
[62] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 339
[63] Yergin, D.: The Quest, 2011, p. 233

were subject to criticism by the oil industry, even in ridiculous ways. Nevertheless, oil production in the US peaked in 1971, so his model is now used for global oil reserves, but with much uncertainty.[64]

2.5.3 Criticism on Hubbert's Peak Oil Theory

When critics look at Hubberts model of future oil production, they point out that Hubbert didn't take two key elements into account: technological progress and price.

In his static view, neither a concept of technological change has been implemented, nor have price developments been considered. In his model, economics are not relevant when it comes to oil production.[65]

The theory embodies an "end of technology / end of opportunity" perspective, but in a typical oil field, only about 35 to 40% of the oil in place is produced using traditional methods. Applying new technologies is dramatically improving the recovery rate. For instance, introducing the digital oil field, where sensors are deployed in all parts of the field, makes it possible to recover an enormous amount of additional oil, by one estimate, an extra of 125 billion barrels of oil – almost equivalent to Iraq's oil reserves.[66]

Moreover, the decline side of the bell-shaped curve mirrors the ascending side. Today's studies show that only some oil fields decline in this symmetrical fashion, but most do not. After reaching peak production, the oil fields often plateau and more gradually decline. Actually, there is no reason why a curve of production of a type of fossil energy should have a symmetrical bell-shaped curve.[67]

2.5.4 The Growing Gap

Discussing Peak Oil is a complicated issue. Taking into account many interest groups and different opinions combined with the uncertainty of officially reported oil reserves numbers, a forecast for oil is almost impossible. Thus, the critical question is how

[64] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 267
[65] Yergin, D.: The Quest, 2011, p. 236
[66] Ibid, p. 237
[67] Ibid, p. 238-239

much oil can be produced at a meaningful rate in the immediate and foreseeable future? [68]

Future scenarios see a growing gap between demand and supply of oil. At the end of 2010, the world's proved oil reserves were 1383 thousand million barrels, slightly more than were at the beginning of that year.[69] At the 2010 rate of 87 mb/d, more than 30 billion barrels of oil in discoveries, revisions and additions must be located each year in order just to replace depletion of the existing stock. [70] Replacing is very challenging and requires enormous investment as well as a long horizon. On a worldwide basis, natural decline rates in oil fields are about 3%.[71] Hence, discovery rates alone cannot meet the current demand of oil. From today's perspective, the world oil discovery rate peaked in the 1960s. Although additions play an increasing role in the oil supply, the reality is that the volume of oil ultimately produced cannot exceed the area under the discovery curve. [72]

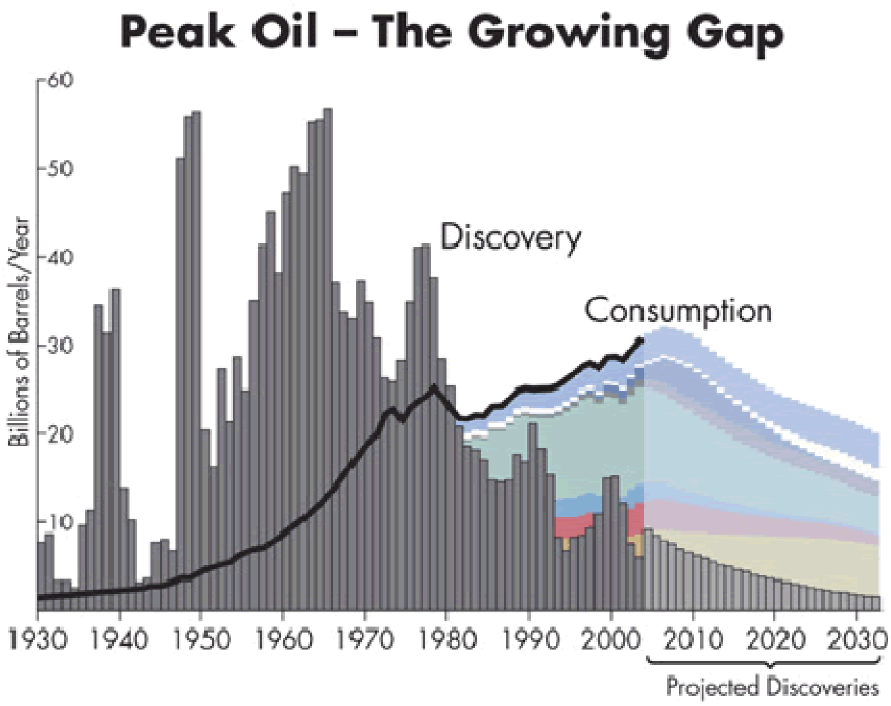

Figure 2.12: The Growing Gap, Source: Association for the Study of Peak Oil (ASPO), 2012, http://www.aspo.ch/wird-weniger-erd%C3%B6l-gefunden.html

[68] Odland, S.: Strategic Choices, 2006, p. 26
[69] Yergin, D.: The Quest, 2011, p. 239
[70] Odland, S.: Strategic Choices, 2006, p. 21
[71] Yergin, D.: The Quest, 2011, p. 239
[72] Odland, S.: Strategic Choices, 2006, p. 21

Confronted with increased demand, new oil discoveries, revisions and additions must exceed the amount consumed. As CEO of Halliburton, Dick Cheney, described the dilemma:

> "From the standpoint of the oil industry (...) for over a hundred years we as an industry have had to deal with the pesky problem that once you find oil and pump it out of the ground you've got to turn around and find more or go out of business. Producing oil is obviously a self-depleting activity. Every year you've got to find and develop reserves equal to your output just to stand still, just to stay even."[73]

Looking at each of the major critical influential components of the growing gap, the following can be stated:

- **New reserves**: As mentioned above, many OPEC countries are not audited by external sources which results in probably overestimated potential oil reserves. It can be assumed that no new reserves have been found since the 1970s. Actually, some countries and companies admitted to have overestimated their own resources. Examples are Royal Dutch/Shell, which overestimated its oil and gas reserves by 22% (which equals 4.5 billion barrels), Kuwait, which admitted its largest field reserves are half of what was expected and Mexico's largest oil field, dropping to 685.000 barrels per day, down from its peak output of 2.1 mb/d.[74]
- **Demand**: Annual oil consumption rose between 1990 and 2000 by 14%, with expectations to reach 110 mb/d (compared to today's 87 mb/d) in 2030, considering the growth especially in Asia Pacific.[75] Moreover, providing the capacity of 110 mb/d in 2030 will require access to oil for further development of current and new projects. Without that access, the future supply picture becomes more problematic.[76]
- **Recoverability**: Logically, resources which are the easiest to access are exploited first. Oil extraction follows the same principle, so oil resources which are more to difficult to access are exploited later. Accordingly, the remaining

[73] Aleklett, K.: Dick Cheney, Peak Oil and the Final Count Down, 2004, p.1
[74] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 264
[75] Ibid, p. 264
[76] Yergin, D.: The Quest, 2011, p. 239-241

oil is located in more remote areas and is much more difficult to extract. From an economic point of view, billion barrels of oil might be unrecoverable. [77]

[77] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 265

3 The Interdependencies between Global Trade, Transport and Oil

"Globalization is a fact of life. But I believe we have underestimated its fragility."

– Kofi Annan[78] –

3.1 Global Trade

3.1.1 History

In the last 50 years, transport demand for passenger and freight grew considerably due to larger quantities of passengers and freight being moved and the longer distances over which passengers and freight are carried. Considering the ongoing growth of mobility, this trend led to a strong increase in global trade and transport demands.

The idea behind trade is to exchange goods and services. The advantages are clear: through trade, a wider variety of goods can be provided, often at lower costs due to economic efficiency (specialization, economies of scale and other related comparative advantages). Another aspect is the space / time convergence: to access wider market coverage with a lower amount of time. Globalized production is accompanied by global trade, and the scale, volume and efficiency of trade has increased since the 1970s. [79]

This is what we call globalization today and this ongoing process has been facilitated by significant technical changes in the transport sector. [80]

3.1.2 Trade as Cause and Effect of Globalization

The trade between countries is an inevitable aspect of today's global economy. The relationships between countries with regard to flows of capital, goods, raw materials and services led to increased spatial interdependencies. Considering the tremendous

[78] Annan, K.: Speech on January 31st, 1999 to the World Economy Forum in Davos, Switzerland, 1999
[79] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 193
[80] Ibid, p. 193

growth in the last years, global trade has been both a primary cause and effect of globalization.[81]

Figure 3.1: Growth in world Trade, Source: Bartel, C., Landy, Y.: Fidelity Asset Management: Think Global, 2012

Global trade flows are reflecting the strategies of multinational companies to reduce manufacturing costs by moving the production to developing countries while maintaining and supervising their supply chains. In addition, the developing countries are new markets as well. Accordingly, developing countries have a growing participation in global trade chains, since they are trading among each other, too.

In 2007, global trade surpassed for the first time 50% of global GDP (see figure 3.1) and will remain to do so. The main reason for this increase is the reduction of the costs of trade: transaction, time costs, tariffs and – of course – transport.[82]

3.1.3 Transportation Costs

Generally, the term transport refers to the movement of passengers, freight or information. Due to the nature of this study (global trade), it will focus on freight alone. The only exceptions to this rule will be data and graphs, where only a

[81] The Levin Institute: Trade and Globalization, 2012
[82] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 194

combined number, for instance passenger and freight, is available. This will highlighted, respectively.

As mentioned before, transport is an enabling factor of international trade without which globalization could not have occurred. Transport has always been linked to economic development and is an embedded part of today's economic function - although sometimes invisible to the customer. With its strategic infrastructure with roads, harbours and airports, it contributes to the added-value of economic activities, facilitates economies of scale, influences land (real estate) value and the geographic specialization of regions. [83]

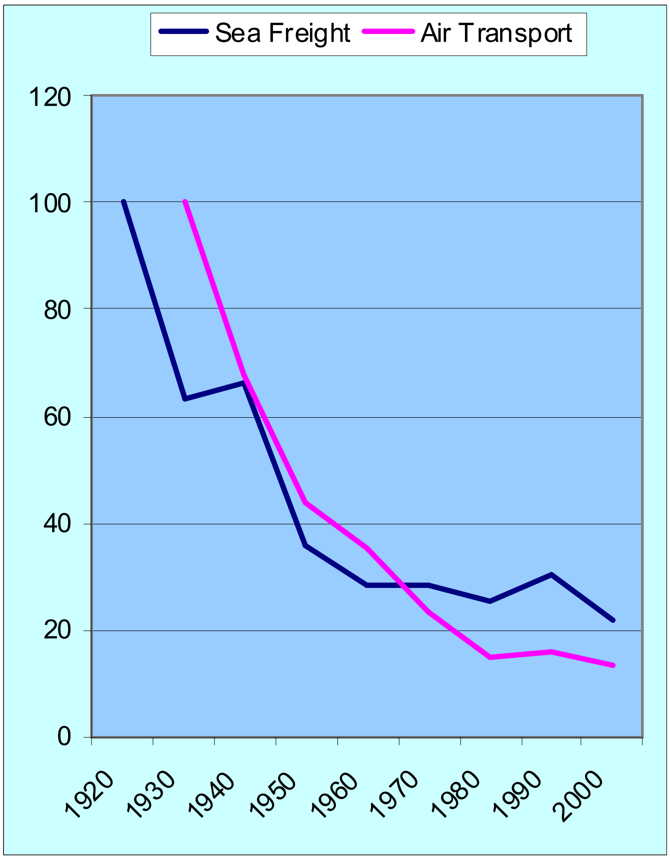

Figure 3.2: Declining Cost Of Transport in percent (at 1990 US$) - Source: UNDP (1999), Human Development Report 1999, p. 30

But global trade could not have been possible without a reduction of transport costs. Although ships and airplanes are expensive to operate, costs per transported unit have dropped significantly over the last decades. Figure 3.2 shows a decline in transport costs from 1920 to 2000. The decline made it possible to overcome larger distances.[84]

To put this perspective: in 1960, the overall cost of logistics compared to total cost of the product accounted for an average of 15% of the value of exports. Today, due to standardization, containerization and specialized equipment the cost of logistics are down in some areas to less than 1% in some areas today.[85] The prosperity of many countries, especially the western contries, would be inconceivable without the low

[83] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 197
[84] Ibid, p. 197
[85] Deutsche Post AG: Delivering Tomorrow – Logistics 2050, A Scenario Study, 2010, p. 150

costs of transport. Also regionally and locally, the oil-based mobility has shaped our lifestyles.

If this efficiency could be applied to all developing countries, the United Nations estimate that a 10% reduction in transportation cost could be accompanied with a growth of about 20% in international and domestic trade.[86]

3.1.4 Dependence on Oil

From today's oil consumption per year, ca. 61% is used for transportation purposes, this is an increase from 42% in 1973 and the share is still increasing. Projections say that between 2000 and 2030 oil consumption will grow by nearly 90%, especially in the developing world. The emerging countries like China and India will be leading contributors with 61% of the world increase.[87]

The transportation sector relies heavily on oil with a share of 98-99%.[88] Only in a few countries does oil account for less than 97% of transportation fuel use.[89] In detail, diesel is the most frequently used energy form for transport, accounting for a share of 87% for trucks and 40% for ships. Ships rely also on heavy oil with a share of 59%, while rail transport splits between diesel (88%) and electricity (12%).[90]

Therefore, the various types of fuel oil are a prerequisite for the transport of large quantities of goods over long distances. Container ships, trucks and planes are not able to move without oil, i.e. the relationship between transport and oil is a direct one.[91]

Since transport is fundamental for providing today's consumer goods, a disruption or turmoil will have an impact on our modern life. Without oil there is virtually no mobility[92] and oil peaking will create a severe liquid fuels problem for the

[86] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 98
[87] Fulton, L., Reducing Oil Consumption in Transport, 2004, p. 4
[88] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 263
[89] Fulton, L., Reducing Oil Consumption in Transport, 2004, p. 4
[90] International Energy Agency, Worldwide Trends in Energy Use and Efficiency, 2008, p. 65
[91] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p.262
[92] Yergin, D.: The Quest, 2011, p. 264

transportation sector.[93] Accordingly, the transport sector is the most exposed part of the economy to oil.[94]

3.1.5 Excurse: Criticism on globalization

But globalization does not only have advantages for countries and the increase in global trade might have a negative effect on people. This criticism is called “anti-globalization”.

Generally, critics claim that free trade promised fairer conditions for the poor, but then globalization has not taken the interests of the developing world into account. Only rich people or big companies benefit from unrestricted free trade at the expense of the poor.

This leads to the argument that globalization only globalizes money and corporations ("corporate globalism"), promoting a corporatist agenda in the name of profit. Moreover, corporate entities have an increasing influence to shape political agendas of nation-states.

Hence, it can be argued that globalization and international trade are restricting the freedom of individuals, people and unions, considering the strict immigration controls in nearly all countries, and the lack of labour rights in many countries in the developing world. [95] This leads to a widening gap between the rich and the poor. [96] Thus, globalization increases the demand for skilled versus unskilled labour and contributes to the negative effects of globalisation: global inequality and the uneven distribution of the new wealth, leading to an enormous growth of slums.[97] Globalization might also be one of the driving reasons behind the Iraq war and other crises, especially the financial crises. Globalization imposes credit-based economics, resulting in unsustainable growth of debt and debt crises. The bailout money (e.g. from the IMF) came with conditions of political change attached, undermining national sovereignty. [98] The rise of “disciplinary neoliberalism,” which places the utmost emphasis on market dynamics, tends to cause significant degrees of

[93] International Energy Agency, Worldwide Trends in Energy Use and Efficiency, 2008, p. 65
[94] OECD Joint Transport Research Center: Discussion Paper No. 2008-5, 2008, p. 4
[95] Frost, M.: Globalization, 2012, p. 1
[96] Machida, S.: Globalization and Citizens’ Support for Global Capitalism, 2011, p. 124
[97] Frost, M.: Globalization, 2012, p. 1
[98] Ibid, p. 1

inequality at a global level.[99] Neoliberal capitalism and the quasi-governments (such as the International Monetary Fund and the World Bank) are not held responsible to the populations that they govern and instead respond mostly to the interests of corporations.[100]

Furthermore, some groups note that globalization can only be sustained at the cost of a large number of citizens in developing countries. According to the “race to the bottom” thesis, economic globalization seriously deteriorates the standard of living in developing countries. Due to highly mobile capital where capital moves freely around the globe, governments in the Third World face harsh competitions to attract foreign investment in order to survive in the global economy. Most governments in developing countries have no choice but to adopt poorer labour regulations, leading to long working hours under harsh working conditions.[101]

3.2 Transportation Segments

3.2.1 Overview Transportation Modes

As discussed in the prior chapters, increasing global trade and a great variety of origins and destinations demonstrate that transport is a fundamental component of today’s global economy. GDP-wise, transport accounts between 6% and 12% in many developing countries.[102]

Generally, transport can be divided into four major segments where a specific mode or system emerged:[103]

- **Sea & Ocean:** The first stage of industrial revolution and mainly used to transport heavy goods. Between the 16th and 18th century, rudimentary and constrained canal systems were developed in Western Europe and North America. These canals were limited to inland distribution.
- **Rail:** In the 19th century, the developments of rail systems were enabled more flexible transportation system, which led to the second stage of industrial revolution.

[99] Machida, S.: Globalization and Citizens’ Support for Global Capitalism, 2011, p. 124
[100] Frost, M.: Globalization, 2012, p. 1
[101] Machida, S.: Globalization and Citizens’ Support for Global Capitalism, 2011, p. 126
[102] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p.83-85
[103] Ibid, p.87

- **Road:** During the 20th century, individual transportation was available to masses due to the development of road systems, highways and automobile manufacturing.
- **Air:** Air transport is the latest transport segment related to global economic activities. This was only possible with the development in electronic communications, especially in the rapidly developing realm of logistics and supply chain management.

Based on collected data from various sources, the author's estimates roughly the shares of global trade performed by the different transport modes in terms of volume, value and energy consumption.

Mode	Volume	Shipment Value
Sea & Ocean	90,0%	54%
Rail	3,0%	1%
Road	5,0%	6%
Air	2,0%	39%

Figure 3.3: Modes shares of global trade's transport activity, adapted and complemented based on Gilbert: Globalisation, Transport, and the Environment, 2006 and own current estimations

Figure 3.3 shows the relations between the respective transport segments. Although no reliable data is available, this table gives an indication of the transport segments.

Concerning energy demand per transport sector, figure 3.4 also gives an indication for all transport segments. The numbers of energy consumption per transport segment include also passenger activity. This is why the road share is at 75%, due to the use of private vehicles for passenger transport.

Mode	Energy Consumption
Sea & Ocean	7%
Rail	3%
Road	75%
Air	15%

Figure 3.4: Share of energy consumption per transport segment, based on various sources and own estimations.

Each transport mode has a specific performance level, related to the desired economic return. As described in figures 3.3 and 3.4, there is often a compromise between value and energy consumption. For instance, high value goods are usually transported by air freight with high speed services, willing to use more energy. On the other hand, Sea & Ocean transport has a low level of energy consumption per unit, but also has lower speed, but is the best transport example for economies of scale.[104]

3.2.1.1 Transport History Cycles

A very interesting topic is looking at the history cycles of transport modes. As shown in figure 3.5, transport went through different waves of transport modes. Following often massive investments in infrastructure and their development, leading to higher level of speed and efficiency – this highlights a paradigm shift. New transport systems grew, matured, declined and were substituted by a new transport mode. In figure 3.5, a peak year is when the mode reaches maturity, and ΔT is the time for the transport system to grow from 10% to 90% of its full extent.

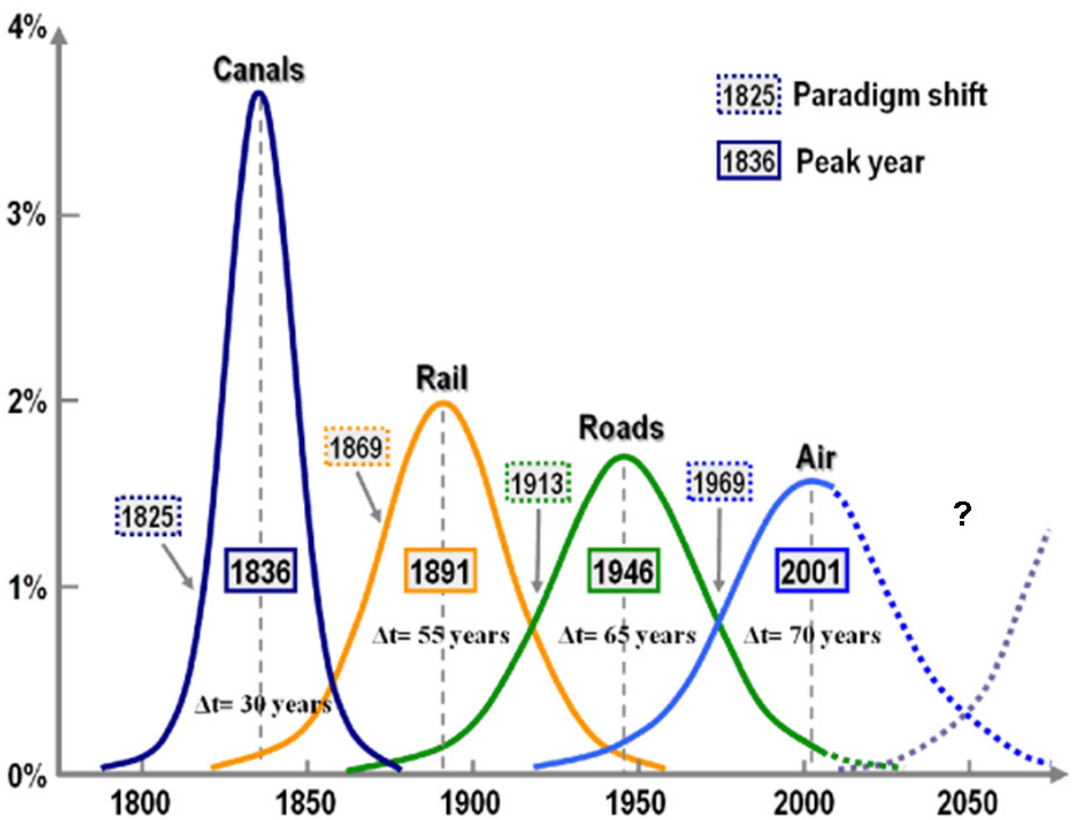

Figure 3.5: Transport History Cycles, Source: Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p.65

Sea & Ocean – Canals: The development of canal systems started around 1805 and peaked in 1836, after 30 years. Main contributor for the paradigm shift was the

[104] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p.262

opening of Erie Canal in 1825, but it matured and declined due to the implementation of rail systems.

Rail: The paradigm shift for rail was the completion of transcontinental railway in 1869. The growth of rail after resulted in almost total service coverage of the American territory by rail. The maturity of rail began with the emerging road transportation in the beginning of the 20th century.

Road: The paradigm shift for road transport was the introduction of car called Model T in 1913. After the development of highway systems, national trade increased between major metropolitan areas along major high capacity road corridors. This lessened the need for regional construction and led to the maturity of road transport.

Air: In 1969, Boeing introduced the Boeing 747 and opened air travel to masses. This marks the paradigm shift in the air transport industry, and was the latest wave of development. This trend is expected to last about 70 years.[105]

Still, air transportation is the main transportation mode for reliable and fast exchange of goods in today's economy, fueling global trade and globalization. So far, no new technology has been developed to replace the air transport.

3.2.1.2 Efficiency of Transport Modes

Within the transport modes, there are significant differences between speed, distance and transport costs. Economies of scale are resulting in lower levels of energy consumption, i.e. lower transport costs. The balancing act transport operaters try to achieve is a compromise between speed (distance) and energy (costs). Naturally, carrying bulk freight is associated with low energy costs; this is a compromise of energy over speed. A compromise of speed over energy could be related to high value goods.[106]

Figure 3.6 shows road, rail and maritime resp. sea & ocean transport with different cost functions C1, C2 and C3 according to the serviced distance.

[105] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p.65-66
[106] Ibid, p.262

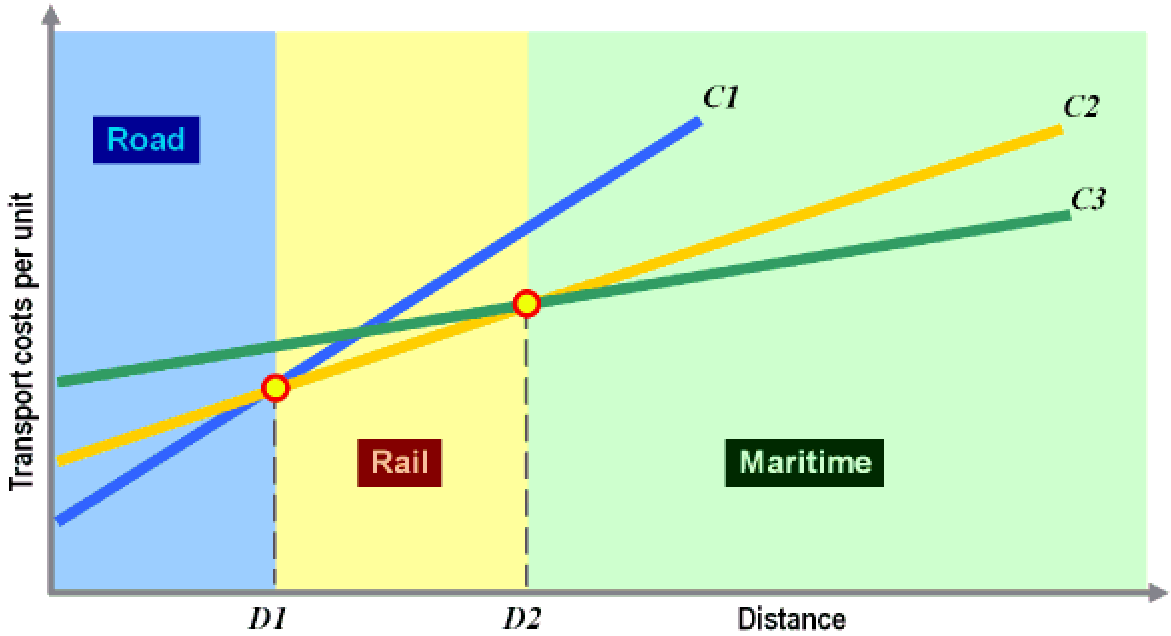

Figure 3: Distance, Modal Choice and Transport Cost. Source: Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 144

The figure points out that road transport has a lower cost function for short distances, but its cost function climbs faster than the other transport modes. At a distance D1, it becomes more profitable to use rail transport than road transport while from a distance D2, sea & ocean transport becomes more advantageous. To put the distances in perspective, point D1 is located between 500-750 km and D2 starts around 1,500 km.

Of course, a change of modal options might not always be possible due to the lack of rail or water for sea & ocean transport. Moreover, for rail and sea & ocean transportation, a terminal is necessary which usually involves road transportation.[107]

To give an indication about the efficiency of the respective transport modes, the United States Marine Transportation System National Advisory Council has measured the distance of one ton of cargo moved with 3.785 liters of fuel (one gallon): A ship operating on inland waterways can move the ton of cargo 857 km.

[107] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p.143-144

This emphasizes the efficiency of sea & ocean transport, since this one ton will move only 337 km on rail and even less on road with 98 km.[108]

3.3 Sea & Ocean

3.3.1 Business Overview

Sea&Ocean transportation by ships is the most effecint way to move large quantities of cargo over long distances. Within the shipping mode, containerized freight has grown substantially versus break-bulk cargo and is dominating today's shipping. Containerization rose from 23% of all cargo in 1980, 40% in 1990 to 70% in 2000. Main routes include oceans, coasts, seas, lakes, rivers and channels.

To handle Sea&Ocean freight, terminals are needed to on- and offload the respective freight, which means an expensive port infrastructure needs to be built, maintained and improved. Steel and petrochemical facilities are adjacent to port sites; actually, no other transportation mode is linked to heavy industries like the sea & ocean transport.

There are two main problems concerning shipping: First, the speed at sea has an average of 15 knots (26 km/h) and secondly, on- and offloading leads to time delays, which could result in several days of handling. This is mainly a problem when goods are shipped over short distances or where a fast delivery is required.[109]

3.3.2 Global Role of Sea & Ocean Transport

Containerized shipping is at the forefront of the process of globalization. Sea&Ocean shipping plays the most important role in global trade, accounting for 90% of global trade in terms of volume and 70% in terms of value. Nevertheless, its nature and its economies of scale make it the most energy efficient mode, only using 7% of all the energy consumed by transport activities. [110]

Sea&Ocean transport activities have grown substantially over the last years. The main drivers are:

[108] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p.263
[109] Ibid, p.263
[110] Ibid, p. 263

- Higher demand of energy, e.g. coal and mineral from developed countries like the US, Europe and Japan. The emerging economies, such as China, are also increasingly involved in importing raw materials for their energy demand.
- Trade liberalization and international division of the production through globalization.
- Facilitating the flows of freight due to technical improvements in Sea & Ocean terminals.

Another main driver is the growth of trade in the transpacific area. The strength of Sea&Ocean traffic does not rest on its speed, but on its capacity and on the continuity of its traffic.

But the main advantage of Sea&Ocean transportation is obviously its economies of scale and the low energy demand, transforming it into the cheapest per unit of all transport modes (see figure 3.7).[111]

Typical Ocean Freight Costs (Asia-US or Asia-Europe)

	Unit	Typical Shelf Price	Shipping Costs
TV Set	1 unit	$700.00	$10.00
DVD/CD Player	1 unit	$200.00	$1.50
Vacuum Cleaner	1 unit	$150.00	$1.00
Scotch Whisky	Bottle	$50.00	$0.15
Coffee	1 kg	$15.00	$0.15
Biscuits	Tin	$3.00	$0.05
Beer	Can	$1.00	$0.01

Figure 3.7: The low costs of sea & ocean transport, Source: IMO, World Maritime Day, 2006, p.9

3.4 Airfreight

3.4.1 Business Overview

Cargo in Airfreight business has increased steadily since the introduction of planes. Traditionally, cargo was carried in the bellyhold of passenger airplanes, but tended to be unreliable mainly due to priority given to passengers instead of freight. Due to the demand of reliable airfreight delivery,

[111] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 263

separate cargo services emerged. Today, dedicated freighters carry about half of all air cargo.

To transport airfreight, most carriers rely on the hub-and-spoke system, using several hubs to reload the freight for final delivery. Today, increasingly long-haul nonstop services are “shrinking the world”, fueling globalization. One of the major issues concerning airfreight is the inefficiency on ground, which accounts for about 70% of the transit time. [112]

3.4.2 Global Role of Airfreight

Air transportation’s share measured in volume accounts only for 2%, but for 40% by value. The most transported goods are high value freight or time sensitive shipments. Airfreight is the main contributor in supporting "just-in-time" production and distribution strategies with low inventory levels. Air cargo also plays an integral role, where fast delivery of supplies prevails over cost issues, such as a computer manufacturer depending of the global shipment of various components to tie together spatially disaggregated operations. [113]

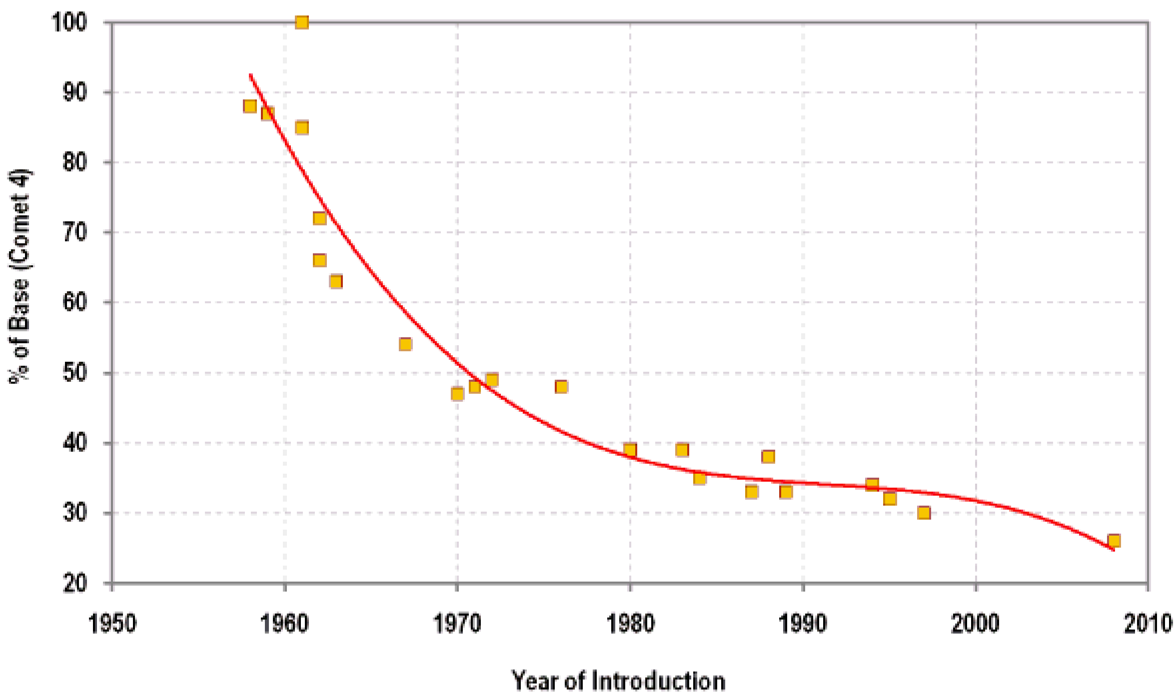

Figure 3.8: Trend in Aircraft Fuel Efficiency (Fuel burned per Seat), Source: Adapted from Aviation and the Global Atmosphere. http://www.grida.no/climate/ipcc/aviation/index.htm

[112] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 136
[113] Ibid, p. 263

Air transportation has high energy consumption levels, accounting for 15% of the world's demand for refined petroleum products. Remarkably, technological innovations such as more efficient engines and better aerodynamics, have led to an impressive environmental track record since the introduction of the jet engine in the 1960s, i.e. -70% of used fuel per passenger and kilometre (s. figure 3.8).[114]

Nevertheless, fuel is the second most important budget for the air transport industry accounting for 13-20% of total expenses. [115]

3.5 Rail

3.5.1 Business Overview

Rail freight transportation has a comparative advantage in carrying heavy bulk. Territorial control makes it possible to carry the freight over long distances with a wide variety of wagons. The recent trend has been a specialization of freight wagons, dependent on the industry and the product. Generally, rail transportation is characterized by using scheduled, but rigid, services as traffic must follow fixed routes and transhipment must be done at terminals. The terminals are usually centrally located and accessible, but are important consumers of space.

Rail freight transportation is also subject to physiographic constraints: Freight transportation rarely tolerates a gradient of more than 1%, i.e. it requires 50 kilometres to climb 500 meters and is leading to higher energy consumption. Although freight trains run at a low speed (in the range of 30-35 km/hr), for turns, the minimal curvature radius is 100 meters, but radiuses of 1 km for a speed of 150 km/hr and 4 km for a speed of 300 km/hr are needed. [116]

When comparing road with rail competitiveness, the breakeven distance needs to be taken into account. Generally, the breakeven distance between rail and truck is in 950-1300 km range. This range is related to regional differences: For instance, in Europe the range is about 1050 km, whereas in the US only 5% of intermodal rail traffic concerns distances of less than 1200 km. This emphasizes the supremacy of

[114] Airbus S.A.S.: Airbus contribution to EC consultation, 2009, p. 2
[115] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 263
[116] Ibid, p. 145

trucks for such a distance. Hence, in the US the breakeven distance is around 1,200 km, but 65% have a length of more than 3,200 km.[117]

3.5.2 The Global Role of Rail Transport

Rail transportation's primary asset is to haul large quantities of goods over long distances in a more efficient way than road transportation and at a reasonable speed. Economies of scale can be easily achieved, because each additional container shows a declining marginal cost, whereas for road transportation each container leads to the same marginal cost increase. [118]

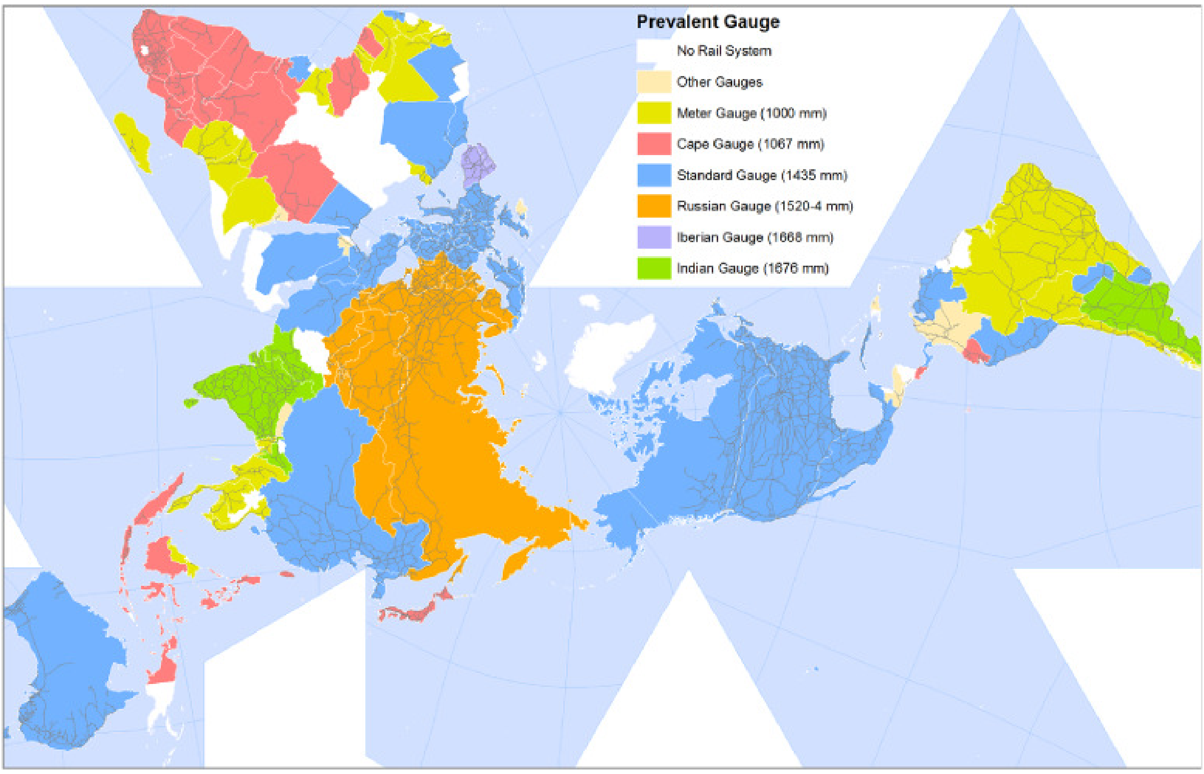

Figure 3.9: Major Gauges of the Global Rail Systems, 2008, Source: CIA World Fact Book

Moreover, rail transport is a 'green' system. While fuel efficiency has increased by 68% between 1980 and 2000, the usage of unit trains, carrying one commodity-type only and double stacking has revolutionized rail transportation with additional fuel efficiency and cost reductions of about 40%. Accordingly, rail freight transport accounts only for 3% of global transport energy demand. To put the energy

[117] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 130
[118] ibid, p. 130

consumption per unit in relation, rail remains twice as efficient for freight movement as road transport. For instance, a 10 car freight train can carry as much cargo as 600 trucks.

Globalization plays a huge role in transforming the rail transport business. Through increasing global flows of goods, new long distance alternatives are emerging. Land bridges in the US and between Europe and Asia underlining the efficiency of rail over long distances. Another point of rail transportation is the combination and extension of Sea & Ocean supply chains simply by carrying trailers.

With railways serving ports and the concentration of container traffic, the strategy is twofold: an increase in the delivery of goods and establishing door-to-door services.[119]

Nevertheless, the market share is rather shrinking than increasing. The main issue complicating the integration of rail systems are different gauges (see figure 3.9).

Six major gauges dominate the global rail systems. The Standard Gauge (1435 mm) is the most common and adopted in the US and Europe. The Standard Gauge accounts for 60% of worldwide railways, followed by the broad gauge (1.520 meters) adopted in Russia and Eastern Europe, accounting for 17%.

The different gauges are the main obstacles of integration, for example between Russia and China as well as Western and Eastern Europe. In the European Union, the interoperability is a major issue. There are plans underway to tackle that issue: First, the liberalization of railway system resulting in a separation of passenger and freight operations. Second, implementation of high speed trains by opening up daytime slots and offering high speed rail services. And last, building freight only tracks and open up the freight business to companies (this has already been completed already in the Netherlands; Netherlands railway sold a dedicated freight business to Deutsche Bahn).[120]

[119] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 130
[120] ibid, p. 263

3.6 Road Transportation

3.6.1 Business Overview

Freight transportation on road has expanded the most over the last 50 years. Roads are a large consumer of space but with the lowest level of physical constraints among all transport modes. Although technological evolution was a continuous trend since the construction of the first car, it still relies heavily on the internal combustion engine. Road transportation is mainly linked to light industries, where fast and flexible movements of small freight batches are required.

Generally, international freight is brought to port and airport terminals by trucking or rail. That’s why road transportation is mainly concentrated on the "first and last miles" of global distribution. Exceptions in overland transportation are for example trade between the NAFTA countries and within Europe.

Despite that, road transportation also faces some constraints: Vehicles and trucks are rarely able to move outside roads and high costs in road construction to overcome rivers, mountains and other rugged terrains. In addition, road transport systems have high maintenance costs for vehicles as well as for the infrastructure.

Nevertheless, equipped with containerization, road transportation has become a crucial link in freight distribution. [121]

3.6.2 The Global Role of Road Transport

Road transportation accounts with ca. 75% accounts for the greatest share of the world’s energy demand and is almost alone responsible for the additional energy demand over the last 25 years.[122]

Although road transportation has a huge network of roads, it faces geographical disparities. 60 to 80% of road traffic is transported on 20% of the road network. Given the steady increase in vehicles, the road sector faces new challenges, such as: significant growth of fuel consumption, traffic congestion and a multiplication of road accidents.

[121] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 128
[122] Ibid, p. 263

Moreover, technical limits of engines and governmental constraints lead to limited potential to achieve economies of scale. For safety reasons, trucks have weight and length restrictions. In addition, increased vehicle weight leads to high increases in energy demand, which also limits the traction and carrying capacities of road transportation.

However, road transport has many significant advantages over other modes: Low capital costs, which offers new users a more or less easy entry, increases competitiveness and is good for innovations. Another point is the high relative speed of vehicles and the flexibility of route choice, providing door-to-door services.

Given the advantages described above, it is no surprise that road transportation has led to their market dominance for short distance trips.[123]

[123] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 263

4 Future Scenarios: Peak Oil, Trade and Transportation

- The main problem is not the availability of oil in the foreseeable future, but the availability of cheap oil. And that we have to prepare ourselves for the end of cheap and always available oil. -[124]

4.1 Peak Oil – but when? Three assumptions.

Forecasting when Peak oil will occur is probably one of the most difficult challenges. Actually, this study concentrates on the impacts and consequences that will evident when Peak Oil occurs and in its aftermath. Hence, a commitment to a precise date is not necessary. However, considering the development of globally relevant factors, an estimation of a forecast is necessary, since political and economic effects can be expected with a delay of 15 to 30 years.[125]

To give an overview about the different views and aspects, this chapter discusses the various assumptions when Peak Oil occurs and categorizes these opinions in three groups: The Oil Skeptics, the Oil Pragmatics and the Oil Idealists.

To include all factors for predicting a date is a complex issue. The supply side alone has many uncertain factors, such as: poor and unreliable data reporting; the rate of new oil discovery; disruptions of existing or planned production and infrastructure constraints. Taking the demand side into account, we need to add: uncertainty of economic growth; demand and investment capital and alternative fuels.

Given these uncertainties, the forecasts vary greatly. The forecasts range from industry analysts expecting Peak Oil until 2020, while others expect the peak to plateau, with a date of 2035 or later. Other, like the EIA, is predicting Peak Oil sometime between 2021 and 2067.[126]

Forecasting Peak Oil based on reserves, production and consumption is simple maths. Total reserves are estimated to be around 1,800 to 2,200 billion barrels, from

[124] Le monde diplomatique, Atlas der Globalisierung, 2010, p. 79
[125] Zentrum für Transformation der Bundeswehr: Peak Oil: Sicherheitspolitische Implikationen knapper Ressourcen, S. 5
[126] Wood, J., Long, G., Morehouse, D., Long-Term World Oil Supply Scenarios, 2004

which about 1,080 billion barrels have been consumed until 2005. 1,000 billion are proven reserves and another 500-600 billion will be exploited for reasonable assumptions. Accordingly, 1,500-1,600 billion barrels thus remain to be extracted. Since ca. 50% of all consumption occurred after 1984 and ca. 90% has been consumed after 1958. Given these facts, the date for extraction of the remaining oil is around 2060.[127]

Forecasting Peak Oil based on official numbers while including other oil forms at the same time is rather complicated. Some argue that although oil production varies immensely between countries, world production of conventional oil from wells on land or in water less than 500 meters is already peaking. A steep decline is expected after 2016. However, due to the strong growth of deep water and non-conventional oil production, the decline could be transformed into a plateau for a couple of years. The main issue with the production of non-conventional is, however that uses energy to get energy.[128]

Forecasts based on already peaked oil fields could also give an indication, when Peak Oil will occur. Although not often known, to date, more than 11 of the 19 countries producing more than one mb/d have already peaked. If the main contributor, the Middle East has reached its maximum of oil production, this will probably result in a continuing growth for a longer period of time, but then falls far more precipitously. The fall could be a worse scenario, since it is questionable how the world is able to cope with this transition. The most critical country for Peak Oil is Saudi Arabia. Saudi Arabia contributes about 9.5 mb/d, with the Ghawar field providing more than half of the Saudi production. It is assumed, if Ghawar peaks, the world will have passed peak oil production.[129]

Forecasts may also consider cycles of shortages and surpluses combined with technological progress. Rising oil prices will make it possible to exploit oil in difficult areas, so deep water drilling or extraction from tar sands could the supply of oil. But technological development could not be able to keep pace with surging demand, and

[127] Odland, S.: Strategic Choices for Managing the Transition, 2006, p. 25
[128] Auckland Regional Council: Price Forecasts for Transport Fuels, 2009, p. 31
[129] Odland, S.: Strategic Choices for Managing the Transition, 2006, p. 25

constructing refineries, pipelines and oil plants is a complex and slow process, involving risks. The main question is how much oil can be pumped to the surface on a daily basis. Some studies predict that innovations like the carbon sequestration could prolong the life of partially depleted oil fields well into the next century.[130] Given the technological progress, Goldman Sachs estimates that oil production from energy projects will amount to about 28 mb/d in 2020. These could more than off set the decline up to 5% from fields currently in operation.[131]

Taking all above aspects into consideration, a key question remains: How will the larger and likely growing number of oil fields affect the future supply of oil? Can the decline be offset by new discoveries, undeveloped known and unknown fields?

No matter what, in order to realize such an offset, large-scale and expensive investments are required. [132] According to the IEA, new development will require investments of about $8 trillion over the next quarter century to handle the larger and more complex geological challenges.[133] These investments are challenging and risky, as despite increased investment activity, improvements in delivery have been slow, showing a lag between planning and delivery. The past years showed an overestimation of project deliveries and therefore present a risk. Depending on the complexity of the project, time-to-build lags can last 10 years or longer, risking a rise in investment costs. A main indicator of such investment costs is the U.S. producer price index for oil and gas well drilling, which almost tripled between 2003 and 2005, suggesting relatively weaker investment incentives.[134]

4.1.1 Three Groups and Assumptions

The interesting issue about Peak Oil is the fact, that according to some calculations, it has already occurred. But the date of the peak has moved forward. First assumption was a peak by Thanksgiving 2005. After that, Peak Oil was predicted after 2007 and then in 2011. Now, sources tell us that there is a significant risk of a peak before 2020.[135] What can be predicted is that after the first half the ultimately

[130] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 266
[131] International Monetary Fund (IMF): World Economic Outlook, 2011, p. 97-100
[132] Ibid, p. 96
[133] International Energy Agency, World Energy Outlook 2010 (Paris: International Energy Agency, 2010), p. 139
[134] International Monetary Fund (IMF): World Economic Outlook, 2011, p. 97-100
[135] Yergin, D.: The Quest, 2011, p. 227

recoverable reserves (URR) of oil have been consumed, the world will be at or near Peak Oil production. [136] Moreover, based upon current and prospective plans, world oil production is supposed to grow from 93 mb/d in 2010 to 110 mb/d by 2030, which is about a 20% increase.[137]

So far, the world has produced about 1 trillion barrels of oil since the start of industry in the 19th century. In order to understand the different views, three groups are representing the different categories of assumptions in their estimates with regard to Peak Oil.[138]

1) Oil Skeptics: URR = approximately 2 Trillion bbl
   Peak is now or within 10-15 years, it is urgent to start preparing.
2) Oil Pragmatics: URR = approximately 3-5 Trillion bbl
   Peak will happen in several decades, there is plenty of time to prepare.
3) Oil Idealists: URR = at least 7-8 Trillion bbl oil equivalent
   Peak is so far away that it is currently not a concern.

4.1.1.1 Oil Skeptics

Oil Skeptics are advocates of the Peak Oil Theory, predicting serious consequences and chaos in industries, governments and economies. According to their theory, 90% of the world accessible oil has been discovered and official reserves are overstated due to political and financial reasons.[139] Oil Skeptics are usually working in earth sciences, the oil industry, agriculture or logistics, critics call them doomers and junk economics. Although they agree that alternative fuels could slow the decline, they are convinced that no alternative can provide the same amount of energy as oil (or be produced at a meaningful rate). They don't agree on the exact date of Peak Oil, but most think it will happen prior to 2020. While some think, production will increase and plateau for 5 to 10 years due to deepwater and non-conventional oil, others believe the peak is approaching and the decline will be steep.[140]

[136] Odland, S.: Strategic Choices for Managing the Transition, 2006, p. 29-31
[137] Yergin, D.: The Quest, 2011, p. 239
[138] Odland, S.: Strategic Choices for Managing the Transition, 2006, p. 29-31
[139] Yergin, D.: The Quest, 2011, p. 227
[140] Odland, S.: Strategic Choices for Managing the Transition, 2006, p. 29-31

4.1.1.2 Oil Pragmatics

Oil Pragmatics rely heavily on oil supply numbers published by official agencies like International Energy Agency (IEA). According to IEA, oil supply will grow at least until 2050, but the numbers are regarded as unrealistic by many geologists. For instance, a five-fold increase in the oil discovery rate was assumed, but did not occur. Many critics see the reserve estimates as political numbers. [141] They don't see the necessity for action, due to the 3-5 trillion barrels of petroleum resources of proved plus probable reserves. Thereof, 1.4 trillion are sufficiently developed and technically and economically accessible.[142] Oil Pragmatics also recognize the importance of cooperation between countries, because in their opinion, if domestic players act on their own, they will struggle to maintain steady oil production in the next 30 years.[143]

4.1.1.3 Oil Idealists

Oil Idealists are pure optimists, who believe in the market and innovation. Usually, Oil Idealists are economists, industry spokesmen or technophiles. They believe high oil prices are a signal and the market will work things out, driving more expensive extraction and conversion into profitable zones. Moreover, in addition to conventional oil reserves, Oil Idealists count alternative supplies on an oil-equivalent basis, including several trillion barrel of oil equivalent like oil sands, oil shale and methane hydrate. Critics state that they mix resources with practicable oil reserves that can be produced economically at a useful rate. In addition, they rely in hypothetical technological innovations which are not even in the R&D stage.[144]

4.2 Global Impacts of Peak Oil

4.2.1 Oil Price Impacts: Future Scenarios

Estimating future oil prices is a complex issue. Nevertheless, based on price elasticities from the past and taking into account economic growth, oil prices can be estimated. Depending on the supply or demand side, prices can develop differently.

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141 Odland, S.: Strategic Choices for Managing the Transition, 2006
142 Yergin, D.: The Quest, 2011, p. 239
143 Ernst & Young: The prospects for oil exploration in Russia: a look at the horizon beyond 2025, 2012, p. 12
144 Odland, S.: Strategic Choices for Managing the Transition, 2006, p. 29-31

The Demand Side - Future Development of Oil Prices: Generally, an increase in GDP growth has been correlated with a global increase in oil consumption.[145] Assuming this direct relation between GDP growth and oil demand, market prospects depend on the income elasticity of oil demand. Given the short-term income elasticity of 0.68 (as calculated in Chapter 2.4) will be kept until 2015, oil demand growth would remain above the growth in production at unchanged prices. Due to very small price elasticities, only substantial price increases are able to balance the market. Assuming a GDP growth of 4.6% annually, oil price will change as follows: if oil supply grows by 1.5% at unchanged prices, then oil demand growth will exceed that of supply by about 1.5% (4.6 × 0.68 – 1.5). With demand price elasticity at –0.02 and no supply response, the oil price should increase by 75% to rebalance the oil market.[146]

The Production side - Future Development of Oil Prices: Assuming world oil production is 1% lower than the historical trend, simulations see an immediate oil price spike of ca. 60% due the unexpected persistent reduction in oil supply growth. Reflecting the very low short-term oil demand elasticity and considering the persistent decline in supply, the real oil price continues to increase. To balance the demand requests, a so-called “demand destruction” is required by the market, which could lead to an oil price increase of about 200% over a 20-year horizon.[147]

Acknowledging the importance of oil for the global economy, a strong rise in oil prices could represent a systemic risk.[148]

4.2.2 Energy Security – Securing the Supply Chain

4.2.2.1 Energy and its Vulnerability

Many people think that energy security or independence is a misleading term, as it should mean “not vulnerable”.[149] But the reality is that today’s energy systems are connected worldwide and vulnerable in many forms.

[145] OECD Joint Transport Research Center: Peak Oil, 2007, p. 13
[146] International Monetary Fund (IMF): World Economic Outlook, 2011, p. 101
[147] Ibid, p. 103
[148] Zentrum für Transformation der Bundeswehr: Peak Oil: Sicherheitspolitische Implikationen knapper Ressourcen, S. 47
[149] Yergin, D.: The Quest, 2011, p. 268

And this does not affect only oil. Liquefied natural gas (LNG) has turned gas into much more of a global business. Moreover, the recent turmoil's showed the vulnerability of the energy system. Hurricane Kathrin and Rita stroke the Gulf of Mexico's Energy complex with an integrated energy shock. It showed how fundamental the integrity of the electric system is for all operational activities. The Internet and reliance on complex information technology systems have created a whole new set of vulnerabilities for energy and electric power infrastructure. The huge earthquake in Japan 2011 took down the region's power system, knocking out services, immobilizing communications and transportation, disrupting the economy and global supply chains and paralyzing efforts to respond to the tragedy.[150]

Furthermore, consuming countries' increasing reliance on oil and gas imports from a much smaller number of producing countries – and most of them politically unstable– heightens global short-term energy-security risks. It reduces the geographic supply and import diversity and increases the reliance on vulnerable supply routes.[151] Energy security needs to be thought of not just in terms of energy supply itself, but also in terms of the protection of the entire chain through which supplies move from initial production down to the final consumer.[152]

Hence, conflicts are not limited to countries anymore. Attacks on pipelines in Saudi-Arabia are mainly the problem for OECD countries.[153] Thus security of transporting energy sources has become another important security challenge to cope with. [154]

The vulnerabilities of such extensive infrastructure can take many forms, also a radicalization of maritime piracy. The Strait of Hormuz and the Malacca Strait are the best examples, the Malacca Strait is only 40 miles in width at its most narrow point. About 14 million barrels per day pass through this waterway. There is also the Bosporus Strait, a half a mile at its most narrow point, transporting three million barrels per day through the middle of Istanbul. These waters and many more are the main routes for the tankers carrying oil and LNG from the Persian Gulf to Europe and

[150] Yergin, D., The Quest, 2011, p. 266
[151] Umbach, F.: Global energy security and the implications for the EU, 2009, p. 1231-1233
[152] Yergin, D.,The Quest, 2011, p. 282-283
[153] Zentrum für Transformation der Bundeswehr: Peak Oil, p. 8
[154] Umbach, F.: Global energy security and the implications for the EU, 2009, p. 1231-1233

the US. Hence, the surge in piracy adds a further dimension of security concerns for the region that holds well over half of the world's proved oil reserves. [155]

Moreover, the following example can help put things into perspective: The USA spend nearly 300$ billion a year for imported energy sources. On top of that, 70$ billion are spend annually on military protection of petroleum supply lines.[156] The energy security of the Gulf region is truly a global question.[157]

4.2.2.2 Shifts in (Geo-)Political Power

But on a global scale, only one oil market exists. This market is complex, let there be a disruption in one part of the world, and the effects will reverberate throughout the market. Security resides in the stability of this market,[158] and volatile supply and demand shocks are only a risk among many others. Many of these risks will be what is called "above ground". These economic, political and military risks will do much to determine the future of oil production. It includes a wide range of questions, such as: What policies do governments make, what terms do they require, what is the quality and timeliness of decision making? Do countries provide companies with access to develop resources and do companies gain a license to operate? What is happening to costs in the oil field? What is the relationship between state-owned national companies the traditional international companies? How stable are countries? What are the threats of war and turmoil in different parts of the world? How vulnerable is the supply system to terrorism? How these questions are played out and interact, are not issues of physical resources, but of what happens above ground and how it affects the shift of powers.[159]

As already mentioned, energy security is not just about countering the wide variety of threats, it is also about the relations among nations, how they interact with each other, and how energy impacts their overall national security.[160] High oil prices will also shift powers within nations, sub-state actors and international organizations. The weight of national states will increase, as only states can provide the political

[155] Yergin, D.: The Quest, 2011, p. 282-283
[156] Smith, W.: Reviving America's Economy, 2012, p.2
[157] Yergin, D.: The Quest, 2011, p. 282-283
[158] Ibid, p. 276
[159] Ibid, p. 228
[160] Ibid, p. 264

instruments of security requirements. Nevertheless, it can be assumed that the Peak Oil future will not be shaped by nations only. The influence of sub-state actors will increase, as will the complexity and the risks of conflicts due to an unfair allocation of resources and wealth. Conflicts could occur, when the power of consuming countries will shift to producing countries, but at the same time have to meet consumers markets and demands. Market-based systems compete with planned economies. Developing countries are directly dependent on industrialized countries while oil companies have a strong influence on international politics.[161]

Oil importing countries are expected to be more pragmatic in their interaction with oil exporting countries. Values, moral and other aspects are playing a more and more decreasing role compared to energy security. Oil exporting countries are likely to use their power to increase their political influence. This will also affect the foreign relations between oil importing countries, because they compete over the limited remaining resources of oil.[162] Furthermore, demands to secure human rights and the western values in oil exporting countries will not be raised in order to secure the supply chain. This results in double standards. [163]

Moreover, a shift of power between National Oil Companies (NOCs) and International Oil Companies (IOCs) is expected. Saudi Arabia, Russia, Iraq and Iran, which together hold 50% of world conventional oil reserves, are not likely to be able to develop of the much-needed resources for the global energy demand, given the constraints imposed by domestic political factors and geopolitical interests. But it reflects a new global business environment: NOCs are able to outspend their rivals of IOCs when paying for licences, and accept lower returns on capital, because their investments are driven by their governments' strategic interests to secure energy supply and long-term geopolitical aspirations rather than by a need to keep shareholders' happy with short-term profits. "The rules of the game" have fundamentally changed the worldwide competition in the energy sector.[164]

[161] Zentrum für Transformation der Bundeswehr: Peak Oil:, S. 8
[162] Ibid, p. 17
[163] Ibid, p. 20
[164] Umbach, F.: Global energy security and the implications for the EU, 2009, p. 1231-1233

Another important point are the oil exporting countries themselves. By 2020, 50% of the estimated total global oil demand will be produced by countries which pose a high risk of internal instability and close to 40% of the world's oil supply is produced in countries that in 1999 had not signed or ratified the main UN human rights conventions or were subject to major criticism by human rights organizations. Of the seven countries that once the U.S. had designated as sponsors of terrorism and ''rogue states'', five (Libya, Iran, Iraq, Syria and Sudan) are energy producers, three (Libya, Iran and Iraq) are major producers to top the world oil market and two (Iran and Iraq) together possess close to 20% of the global proved oil reserves.[165]

Moreover, political factors of ''state-orchestrated strategies'' are determining the access to oil fields in Africa, the Caspian Basin and the Middle East more than ever. The changing energy landscape has already created new political linkages, partnerships and strategic alliances inside and outside of the OPEC such as between Venezuela, Iran, Russia, China and India. In such a political environment, political solutions for regional conflicts will be very difficult to find. [166]

This development will also favour bilateral agreements between nations and the developing countries will increase their influence, e.g. in the UN Security Council. The Middle East and North Africa are likely to build a bloc against the US, in the region as well as in the international system.[167]

The new oil- and gas-rich producer states are threatening their wealth and political stability themselves if they do not use their revenues wisely for sustainable development of their countries and societies in order to avoid a widening internal inequality, which may even lead to civil wars. Effects of a ''resource curse'' and ''Dutch diseases'' have already been identified in many producer states. As a consequence of a failing diversification of their economies, 34 countries rely on oil and gas resources for at least 30% of their export revenue.[168]

[165] Umbach, F.: Global energy security and the implications for the EU, 2009, p. 1231-1233
[166] Ibid, p. 1231-1233
[167] Zentrum für Transformation der Bundeswehr: Peak Oil, 2010, p. 19
[168] Umbach, F.: Global energy security and the implications for the EU, 2009, p. 1231-1233

4.2.3 Economic Impacts

Past trends show that there is a direct interdependency between GDP growth and oil consumption. Based on a 20-year average an increase of 3% in GDP correlated with an increase in oil consumption of 1.6% per year.[169] Despite that, oil's overall cost share as a proportion of GDP is quite small, ranging from 2 to 5% from country to country. For oil importer countries, a supply shock leading to an oil price change has generally an impact on GDP equal to that of the cost share. This is quite small and the worldwide impact including oil export countries – where higher oil prices stimulate demand – could be even smaller.[170] Accordingly, a decline in oil supply will not have a big impact on the global economy. In particular, a downshift in oil supply growth of 1% is supposed to slow annual global growth by less than ¼% in the medium and longer term.[171]

Nevertheless, the risks of Peak Oil or high oil prices should not be underestimated either. Depending on the extent and evolution of oil scarcity, including demand and price scenarios, there is a potential for abrupt shifts, which would have much larger effects than more gradual shifts.[172]
Especially industries and firms producing or using oil-intensive goods are particularly vulnerable to oil price increases. High oil prices can shrink profit margins or even drive companies into loss zones. Reallocation of capital and labor is time and cost-intensive and large-scale bankruptcies may have an impact on the rest of the economy.[173] In particular, given the slow change in our energy systems and transport vehicle fleets, the challenge for global transport will remain.[174]

Taking all these aspects into account, it comes down to three scenarios:

[169] OECD Joint Transport Research Center: Peak Oil, 2007, p. 13
[170] International Monetary Fund (IMF): World Economic Outlook, 2011, p. 122
[171] Ibid, p. 90
[172] Ibid, p. 90
[173] Ibid, p. 122
[174] Australian Government: Transport Energy Futures: Long-Term oil supply trends and projections, 2009, p. 29-31

1. Best Case: Oil is replaced with other energy sources.
2. Business as usual Case: Improved energy efficiency results in energy use per unit of GDP declining markedly to match the shortfall.
3. Worst Case: GDP declines to match the shortfall. [175]

4.2.3.1 Best Case

In this case, all critics would be wrong. Hubberts Peak Oil Theory is more or less irrelevant: price and technology changed the ways of oil production and oil supply. When oil fields reach a physical peak of production, they plateau and gradually decline rather than falling sharply in output. Moreover, a plateau is less dramatic and due to the technological changes, the world is still many years away from ascending to that plateau. [176]
Moreover, oil can be replaced with equally rich and abundant energy sources like alternative fuel sources, e.g. gas-to-liquids, coal-to-liquids, electricity, hydrogen. Another scenario is that global economic slowdown could lead to lower demand of oil, which will be the limiting factor for oil production. As lower GDP growth is accompanied by lower oil prices, the impact will be marginal.[177]
Given all these above mentioned factors, there is no real change to today's scenario.

4.2.3.2 Business as usual Case

In this scenario, oil production cannot keep up with the demand. A conversion of oil is not possible and a large number of states are not in a position to make the required investments in time to change their oil behaviour.[178] This results in high and volatile oil prices, resulting in far-reaching consequences.[179] The most important consequences of a reduced oil supply rate are described below:

a) Energy Security: Countries will take actions to assure their long-term access to oil. It becomes a key factor in the redesign of international relations. Economic strength, military strength, or possession of nuclear weapons will be a primary tool of power

[175] Australian Government: Transport Energy Futures: Long-Term oil supply trends and projections, 2009, p. 29-31
[176] Yergin, D.: The Quest, 2011, p. 238
[177] Australian Government: Transport Energy Futures: Long-Term oil supply trends and projections, 2009, p. 29-31
[178] Zentrum für Transformation der Bundeswehr: Peak Oil: Sicherheitspolitische Implikationen knapper Ressourcen, 2010, S. 14
[179] Odland, S.: Strategic Choices for Managing the Transition, 2006, p. 14

projection and a determining factor of new dependencies in international relations. [180] Moreover, decreasing oil supply increases the risks of conflicts between the agricultural, petrochemical, transportation, heating and electric power sectors.[181]

b) Transportation Costs: Today's global economy depends partly on 12,000- mile-long merchandise supply lines fueled by cheap oil. All transport modes will see an increase in energy prices. For private vehicles, fuel will consume a bigger portion of family income and freight or travel by air might become too expensive for the middle class.

c) Food Prices: The increase in food prices is twofold: Farmers will face higher fueling costs associated with planting, growing and harvesting as well as with higher prices for petrochemical feedstocks. In addition, transportation cost will rise, which will lead to decreased profit margins. This affects country-grown as well as imported food.

d) Cost of Living: More expensive transportation, increasing food prices and higher oil-related costs of manufacturing will be passed onto the customer. This will significantly increase the cost of living. While developed countries face "only" higher prices, many developing countries face food scarcity.

e) Global Economy: Due to the high cost of living, consumers will spent less on clothing, grocery, cars, electronics and tourism, to name a few. This affects just-in-time global fabrication/assembly companies, which may become uncompetitive. These are signs which could lead to a global recession.

f) Regionalization: The increase in oil prices will lead to a revival of regional and local economies, making local agriculture necessary and cost-competitive again. Countries in which the industrial base is mainly off-shore will suffer until local manufacturing can be re-established.[182]

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[180] Zentrum für Transformation der Bundeswehr: Peak Oil: Sicherheitspolitische Implikationen knapper Ressourcen,2010, S. 14
[181] Odland, S.: Strategic Choices for Managing the Transition, 2006, p. 14
[182] Ibid, p. 14

4.2.3.3 Worst Case

This scenario describes the dramatic consequences after Peak Oil including the so-called “Tipping Point”.
Intuitively, a slow phase of declining oil production leads to a slowly declining economy. The usual assumption is that Peak Oil will set back prosperity levels for a while, but after technological solutions are found, the world will return to prosperity again. This intuition is deceptive: economies are relatively stable. Short-term fluctuations and other shocks are possible, but the basic economic principles still work. Peak Oil could be a scenario, when systems do not react reasonable, but in a chaotic way.

Tipping points are characterized by chaotic reactions. In this scenario, an economic tipping point exists when – after Peak Oil - the world economy shrinks for an uncertain time. This results in a chain reaction destabilizing the economic system.

The main assumption for the following scenario is a drop in the outpour of conventional and non-conventional oil. This decline can not be offset by non-conventional oil, at least not in the foreseeable future. The term "foreseeable" is of particular importance. It ultimately leads to a loss of confidence in markets.

<u>Short-term consequences:</u>
In the short term the global economy will respond in proportion to the decline in oil supply. Consequences are as follows:
a) Rising oil prices reduce consumption and output, resulting in recessions.
b) Rising costs of transportation lead to higher prices of all traded goods. Global trading volumes decline, which leads to declining revenue streams in companies and to food shortages in some countries.
c) Government budgets are subject to extreme pressure. Expenditures for securing the food supply and social spending due rising unemployment are competing with subsidies in oil substitutes and Green Tech. Moreover, government income is declining drastically due to the recession (less taxes).[183]

[183] Zentrum für Transformation der Bundeswehr: Peak Oil: Sicherheitspolitische Implikationen knapper Ressourcen, 2010, p. 48

<u>Mid-term consequences:</u>

In the mid term, the global system collapses.

a) Economies begin to realize the contraction and are assuming a shrinking global economy for an uncertain time.

b) Tipping Point: Due to the shrinking economy, companies make hardly any profits, resulting in problems to pay debts or distribute profits to investors. The banking system, stock exchanges and financial markets are collapsing.

c) The financial markets are the backbone of the global economy and an integral part of modern societies. The collapsing of the financial markets leads to a loss in confidence in currencies, collapsing of supply chains, national bankruptcies and rising unemployment.[184]

4.3 Transportation Impacts

An increase in freight transportation costs can have a serious impact. The specialization of today's global supply chains has been made possible by the technological progress within the freight transportation sector. The freight transportation sector is mainly based on fossil fuels, and a conversion to non-fossil fuels is currently not possible. [185] Figure 4.1 shows the additional energy demand for the transport sector until 2050. Oil demand has risen (37%, 1990-2006) and is still rising, leading to more importance on the political agenda, to be followed by technological research.[186] In particular in regional and local areas, fossil mobility is a basic requirement for the economy. A restriction to the mobility would have immediate impacts on trade and prices.[187]

To understand the impacts on transportation for the future, a closer look on how innovation in transport works will be provided.

Looking at the different transport modes, each mode is characterized by different technologies. Due to geographical and technical specificities, different rates of innovation and diffusion are developed. Hence, new technologies make existing

[184] Zentrum für Transformation der Bundeswehr: Peak Oil: Sicherheitspolitische Implikationen knapper Ressourcen, 2010, p. 49

[185] Ibid, S. 72

[186] European Intermodal Assocation (EIA): Public Consultation on the communication on a sustainable future of transport, 2009, p. 4

[187] Zentrum für Transformation der Bundeswehr: Peak Oil: Sicherheitspolitische Implikationen knapper Ressourcen, 2010, p. 73

modes more efficient, being a competitive force. Innovation can also have a destructive impact, substituting old technology by new technology and thus marking a paradigm shift. However, innovation can be delayed by industry interests and the simple fact, that the older technology is wider adopted, and can only be replaced by heavy capital investments.

Former trends show that technological innovation is always linked to innovations for faster and more efficient transport systems. The main achievement is that a greater amount of space could be exchanged in a shorter period of time. The outcome of these innovations is the direct link between the technological evolution and economic development. Accordingly, there is an interdependency between economic development and transportation.[188]

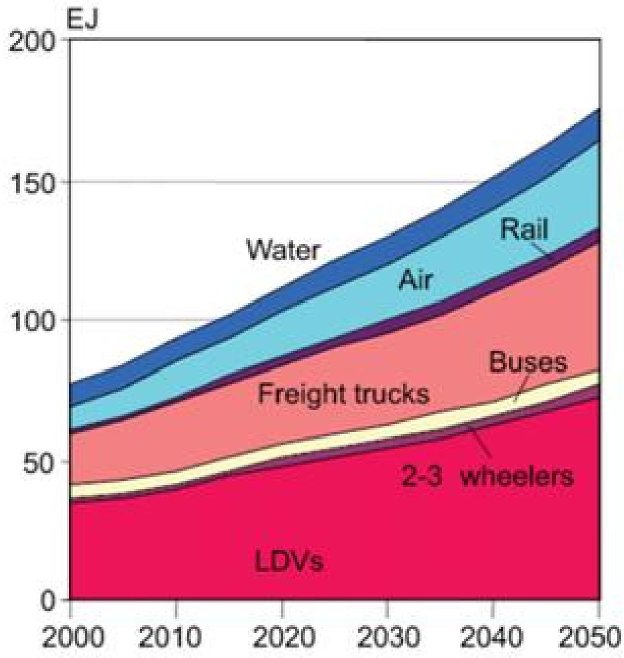

Figure 4.1: The increased energy demand in transport, Source: Van Essen, H.: Increased International Road and Rail Freight Transport, 2008, p. 9

Of course, as we have done before, we could look at the past to predict the future. The general assumption for future transport is to use existing technologies, but with greater speed, mass availability, a higher capacity and/or a better accessibility - all this even with lower costs. In short: simply operating at an extended scale beyond what is currently possible. The perspectives include speculations, but also a distorted reality.

Predicting the future involves three activities: forecasting, scenario building and speculation. The difference between forecasting and scenario building is the change of assumptions in its parameters. When forecasting, parameters do not change much, while scenario building involves expected fluctuations in parameters. Accordingly, forecasts are more near-term calculations, while scenario building tries to predict various types of outcomes.

[188] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p.65-66

Predictions are generally not capable of anticipating paradigm shifts, which involve new technologies and change in economic and social factors. Moreover, if new technologies are considered, it is often assumed that the new technology will spread widely over a short period of time. In general, innovations follow a cycle (introduction, adoption, growth, peak, obsolescence) over several years or decades.

When we talk about the future of transportation, in particular over several decades, much of what is being presented is unlikely to become reality. The progress made is astonishing, who could have imagined today's transportation scenario 100 years ago? We may face the same limitations at the beginning of the 21st century, but by impressive technological innovations as well as a better understanding of physics, we might be better positioned to determine future transportation trends.[189]

4.3.2 Potential Impacts of High Oil Prices on Transportation

High transport costs have a significant impact on international trade. An increase of 10% in transport costs correlates with a decline in trade volumes by 20%.[190] Although oil prices may remain moderate in the short term, the high growth of energy demand will lead to higher prices, since the reliance on fossil fuels is still high and falls rather more gradually.[191] The main problem for the transportation industry is the delay or even the possibility to pass fuel costs to customers when prices rise rapidly.[192]

Figure 4.2 shows that transport costs are highly sensitive to oil prices. In some areas, fuel account for almost half of total freight costs. Accordingly, high oil prices have a direct impact on transport costs. Roughly, every one dollar rise oil prices translates to 1% rise in transport costs.[193]

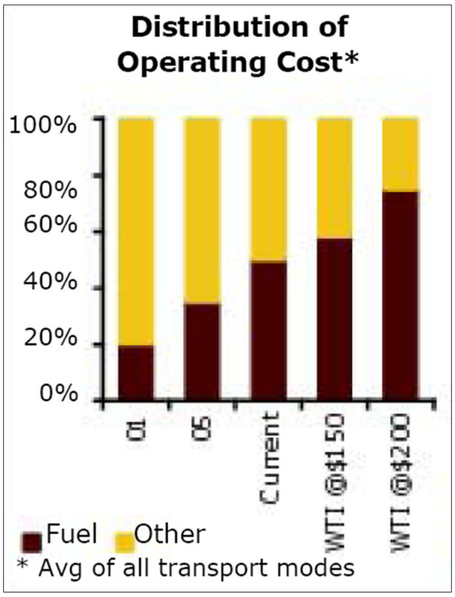

Figure 4.2: Distribution of Operating Costs, Source: Rubin, J., Tal, B.: Will Soaring Transport Costs Reverse Globalization?, 2008, p.4

[189] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p.65-66
[190] Ibid, p. 98
[191] World Energy Council: Global Transport Scenarios 2050, 2011, p. 31
[192] OECD Joint Transport Research Centre, Oil Dependence, 2008, p. 19
[193] Rubin, J., Tal, B.: Will Soaring Transport Costs Reverse Globalization?, 2008, p.4

There are many different views of the future role of oil and fossil resources in the transportation sector and estimations vary widely. It is assumed that total fuel demand in all transport modes will increase by 30%-82% over 2010 levels between 2010 and 2050. Transportation still relies heavily on gasoline, diesel, and jet fuel, contributing 80-88% of transport market fuels. Until 2050 the demand of these three fuels will increase by 10-68%, with jet fuel growing by 200-300% and diesel with 46%-200%. Gasoline will decline, but is more or less offset by biofuels, increasing almost four-fold. Other energy modes like electricity, hydrogen, CNG and methanol are expected to increase six-to seven fold.[194]

Given these changes in fuel consumption combined with high oil prices, the following impacts can be expected:[195]

a) **Usage level:** At the beginning, price increases are absorbed under the expectation of a temporary change and may have a limited effect. But afterwards, high oil prices will lead to restrictions and the rationalizing of resources. This can be the reduction of frequencies for airlines, speed adjustments or cutting extra resources until the transport vehicle is on capacity.
b) **Modal shift:** High oil prices could lead to using alternative modes of transportation, once a price threshold is reached. In this scenario, the goal of the modal shift is to change to a less energy intensive mode. In practice, trucking will shift towards rail and public transit will also gain market share.
c) **Service area changes:** Every transport mode follows a distance where it provides mobility at an optimum cost. High oil prices can change these distances with regard to their mode and the cost / distance function. This could be a truck, where at 1000 km the freight is loaded on rail, but the high oil prices shift this distance to 800 km.
d) **Gateway / Hub selection:** High oil prices could change the relationships between gateways, especially at intermodal locations, e.g. instead of using a port with faster and more energy intensive hinterland connections, the

[194] World Energy Council: Global Transport Scenarios 2050, 2011, p. 65
[195] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 264-265

gateway closer to customer may be used. This could result in longer transit times, but the cost trade-off would make it up.

e) **Network configuration:** Due to high oil prices, transportation modes can switch configurations. The best example is an airline cutting less profitable routes and offer more direct point-to-point services, which leads to an abandonment of marginally provided services, namely at small airports.

f) **Supply chain development:** Along the supply chain, there are many ways to influence changes in its cost structure. High oil prices can lead to changes within the supply chain to optimize the cost structure. To give an example, higher packing density of parts for an increased level of transport asset utilization may result in delays of assembly tasks along the supply chain. Some of these costs could be absorbed by higher efficiencies, but could also result in higher consumer prices.

g) **Location choice:** Low transport costs are triggering the comparative advantages in global trade for producing off-shore. Due to high oil prices, locational choices are significantly impacted, meaning a change in manufacturing sectors with sites closer to final markets.[196]

As discussed in the chapters before, fuel oil is price inelastic, meaning high prices have a limited impact on the average annual growth rate of motorization.[197] Nevertheless, high fuel prices are also leading to the development of alternatives of fuel. The common approach to deal with high oil prices is three-folded: increasing technical efficiency of existing and future vehicles, increasing the production and use of bio-fuels and the aggressive adoption of hydrogen and fuel cell vehicles.[198]

4.3.2 Oil substitutes

The transport industry is still dominated by petroleum-derived fuels due to the relative simplicity using it in the internal combustion engine vehicle. Although other fossil fuels like natural gas, propane or and methanol can also be used as transportation fuels, they require a more complicated storage system and large-scale capital investments for its distribution.[199]

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[196] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 265
[197] Ibid, p. 266
[198] Raina, R.: Agricultural Trade after the Peak Oil, 2010, p. 22
[199] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 263

Since 1979, the idea that the world needed a transition to renewables had already become a clear trend in energy thinking. The Arab oil embargo and the Iranian Revolution brought fears about the future of world oil. Even at that time, this made renewable energy the natural solution.[200]
But in the recent years, no substantial substitution for oil in recent years has been developed or found, but new technologies are emerging in the transportation sector. Using these new technologies in the transportation sector will be challenging, but it can be assumed that some alternative fuel options become economically viable if high oil prices remain.[201]

Given the current market conditions, the introduction of alternative energy forms is leading to an increase in consumption of both fossil and alternative fuels. It will probably not lead to a substitution of crude oil by bio-based alternative fuels. Alternative energy forms are rather complementing existing supply than replacing it.[202] If you measure the scale of renewable energy in terms of dollars, total investment reached $150 billion in 2009, four times higher than four years earlier. Although they account only for about 3% of the world's electricity, it also accounted for almost 50% of the new capacity added in 2007 to 2009. In short: renewables are becoming a substantial business.[203]

Given shrinking oil reserves, increasing petroleum costs and the need to reduce emissions, alternative fuels in the form of non-crude oil resources are increasingly important, although they are far from being a dominant energy resource. The actual role and market will be determined by the interplay of policy, economics and innovation. Each technology has its own story and its own distinctive prospects and challenges.[204]
The most promising alternatives being considered are: Biogas, Hydrogen, Electricity, Hybrid Vehicles and Coal Liquefaction.

[200] Yergin, D.: The Quest, p. 523
[201] International Monetary Fund (IMF): World Economic Outlook, 2011, p. 96
[202] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 266
[203] Yergin, D.: The Quest, p. 546
[204] Ibid, p. 546

4.3.2.1 Biogas

The term biogas includes ethanol, methanol and biodiesel. The production faces two main problems: Low productivity and an energy-intensive process.

Producing biogas requires large harvesting areas, but the capacity of plants is limited to absorb solar energy and the transformation through photosynthesis. Productivity is low and does not meet the energy needs of the transportation sector, for example: Given the objective of reducing oil consumption by 20% in the US by using ethanol, it would require nearly 115 billion litres by 2017, which is the total amount of annual US corn production. [205]

As mentioned, is it also energy-intensive: Producing one thermal unit requires the 0.76 unit of coal, petroleum or natural gas. Choosing a biomass fuel will mainly be related to the energy efficiency of the production process. [206]

4.3.2.2 Hydrogen

Although the process of using hydrogen as a transportation fuel is quite complex – for instance storing it onboard of the vehicle and using fuel cells - is often referred to as the energy source of the future. This is because hydrogen fuel cells are two times more efficient than gasoline and generate near-zero pollutants.

Hydrogen has also some drawbacks: it has a very low energy density and a lot of energy is wasted during production, transfer and storage. Moreover, manufacturing requires electricity production and hydrogen energy used in vehicles requires 2-4 times more energy for operation than an electric car. It also requires very low temperature and a high pressure storage tank, which adds weight and volume to the vehicle. Considering these facts, liquid hydrogen fuel would be a better alternative for ship and aircraft. [207]

4.3.2.3 Electricity

Electric vehicles are considered a critical alternative to hydrogen fuel and fossil fuel vehicles. The production of an all-electric car is also easier and cheaper compared to a fuel-cell vehicle. The problems with electric cars are the lack of storage systems and the incapability of driving ranges and speed compared to conventional vehicles.

[205] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport Systems, 2009, p. 266
[206] Ibid, p. 266
[207] Ibid, p. 266

Although the low energy capacity of batteries makes the electric car currently less competitive against the internal combustion engines, there are enormous investments in the R&D of batteries improving speed and increasing distance. [208]

4.3.2.4 Hybrid vehicles

Hybrid vehicles are a combination of internal combustion engine with an electric motor and batteries. It uses liquid energy as main source, but the engine is also used to charge the battery via a generator. This results in great overall fuel efficiency. Considering the possibility of Peak Oil, the successful development and commercialization of hybrid vehicles appears on the medium term the most sustainable option to conventional gasoline engine powered vehicles. [209]

4.3.2.5 Coal Liquefaction

Approaching peak levels in conventional oil production, some countries see coal liquefaction technology as an answer to transport fuel demands. The process transforms coal into refined oil after a series of processes of high temperature and high pressure. There is currently an uncertainty of the cost-effectiveness of this process, but for coal-rich countries like China and South Africa, coal liquefaction plays a huge role in transportation fuel strategies.[210]

4.3.2.6 Threshold Calculation

All above mentioned substitutes suggest a higher relation of alternative energy costs in the transportation sector than in other types of economic activities. Industrial, household, commercial, electricity and heat sectors will face more competition and are more likely to shift away from oil and to rely on solar, wind or hydro-power. Ultimately, renewable energy sources for transportation might not be competitive with liquid fuels unless future prices are affected by increasing fuel taxes considering environmental impacts.[211]

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[208] Ibid, p. 266
[209] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 266
[210] Ibid, p. 268
[211] Ibid, p. 266

To understand the impact and the problems of fuel alternatives, here is an example which will help to determine the threshold at which alternative options become economically viable:

Assuming a cost premium for a plug-in electric car of $2,000 plus value mileage limitations and other logistical problems specific to electric cars of $1,000 a year, there is a total premium of $3,000 over gas-engine cars.
Now, we need to calculate the breakeven point: in this scenario the operating costs of an electric car versus a gas-engine car is equal to the premium.
We take the average fuel consumption per vehicle of ca. 600 gallons and the retail gasoline price of roughly 0.035 times the imported oil price (plus taxes).
If we assume the retail price of electricity for cars at 20% of gasoline prices, the calculation results in a price for imported oil in the US of ca. $155. Moreover, other factors could affect our calculations—for example, on the downside, increasing marginal costs of ramping up production that starts at a very low level or, on the upside, technological improvements and increasing returns to scale in the production of electric cars.[212]

4.4 Sea & Ocean

4.4.1 Impacts on Energy Use

The effect of high oil prices for to the Sea & Ocean Industry has many aspects and will lead to a change for of fuel use. To underline the impacts of high oil prices, the following example will put the increase in perspective: When oil prices were at $20 a barrel, a standard 40-foot container from Shanghai to the US East Coast had costs of $3,000. At today's level of oil prices, the costs are at ca. $8,000, an increase of more than 250%. Assuming an oil price of $200 per barrel, costs will rise to ca. $15,000, almost doubling.

Moreover, the ship speed and its distance are also important factors. Due to less time spent in ports, ship speed plays an even more important role. The general assumption of faster speed leading to an increase in energy is also valid for the Sea

[212] International Monetary Fund (IMF): World Economic Outlook, 2011, p. 96

& Ocean Industry. Given today's oil prices, a 10% increase in trip distance correlates with a 4,5% increase in transport costs.[213]

Nevertheless, fuel use for container shipping is expected to rise more in the future, simulations project an increase up to eight-fold until 2050. [214]

Given the increase in fuel consumption and high oil prices, there are two ways to tackle these issues: innovations and energy efficiency.

For the Sea & Ocean sector, innovations include propulsion systems, alternative fuels and aerodynamic design:

- Propulsion systems: Hybrid technology for ships is currently no option due the poor performance of battery power. The most likely option with regard to propulsion systems is the fuel cell technology, which is already used commercially today. The fuel has also some drawbacks: so far, no mass production exists, large-scale investments are required, but unlikely due to the short lifetime of fuel cells and the uncertainty if fuel cells can be pushed through into the market.
- Alternative fuels: Besides alternative fuels, other energy forms could be asubstitution to fuel: Using wind can cut fuel consumption by approximately 15%, using a towing kite in the shape of a paraglide, which can be fitted to all common cargo vessels. With regard to sun power, solar ships equipped with an on-board solar energy generator should also be considered for future application.[215] Taking into account alternative fuels, ship engines are capable of using a wide range of fuels. The main possible fuels for Sea & Ocean transport are biofuels and biodiesel, but their uptake is highly dependent on oil prices.[216] Due to the increasing prices, forecasts see a 30% share of biofuels by 2050.[217]
- Aerodynamics: Redesigning the basic structure of the hull in terms of hydrodynamic performance can increase energy efficiency by 15%–20%.[218]

[213] Rubin, J., Tal, B.: Will Soaring Transport Costs Reverse Globalization, 2008, p. 5
[214] Ibid, p. 5
[215] Deutsche Post AG: Delivering Tomorrow, p. 116
[216] International Energy Agency: Transport Energy and CO2, 2009, p. 364
[217] Ibid, p. 39-40
[218] Deutsche Post AG: Delivering Tomorrow, p. 116

Another point to reduce oil consumption is to increase energy efficiency. But so far, ship efficiency has improved significantly in recent years. Looking into the future, research identified a lot of small improvements in efficiency for the Sea & Ocean industry. When executed, the energy used could be reduced up to 50% per ton-kilometer.

One of the most effective adjustments to rapidly reducing fuel consumption is to reduce speed. According to studies, the difference between fuel consumption and optimum fuel consumption is up to 26%.[219]
Another effective way to increase energy efficiency per ton-kilometer is to increase ship size. This has been done in recent years and will continue to be done, but it is subject to limitations.[220]

4.4.2 The Future Role of Sea & Ocean

High oil prices also have an impact on the economic situation of Sea & Ocean transport, but compared to road and airfreight it is less affected. The Sea & Ocean mode is the most energy efficient, but nevertheless increasing fuel prices will change the landscape for the whole sector. As mentioned, in the short-term, operators and shippers will respond to high prices with a lowering in speed. However, in the long-run, high oil prices will lead to a lower demand for long distances transports, increasing short services on coastal and fluvial areas and the developing of efficient hinterland connections.[221]

Building efficient hinterland connections leads to a growing number of entry points on coasts, to avoid unnecessary traffic. [222] Seaports will play more important roles, serving many main functions from a hinterland perspective. This allows bundling cargo flows and thus economies of scale.[223] The development of seaports is critical for handling increased volumes from domestic and global shipping. As mentioned,

[219] International Energy Agency: Transport Energy and CO2, 2009, p. 360
[220] Ibid, p. 39
[221] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 266
[222] European Commission: White Paper: Roadmap to a Single European Transport Area, 2011, p. 7
[223] Västra Götalandsregionen, Dryport: Extending the role and concept of Dryports, 2009, p. 1

moving goods to the hinterland and linking it to the seas will include the use of inland waterways.[224]

Given the trend of increased volumes on sea and the low-cost structure of Sea & Ocean freight (77 times less than airfreight, 7 times less than heavy trucks and 3 times less than rail), especially food and agriculture transport from developing countries will increase, gaining market share from airfreight business.[225]

Moreover, high oil prices lead to the question if off-shore production is still a better solution. Given high transport costs, quality issues, accessibility and distance, off-shore production might be more expensive than local production.

For comparison purposes: In 2000, with oil prices at $20 per barrel, transport costs were equivalent to a 3% tariff rate in the US. With an oil price at $130, transport costs correspond to a tariff rate of over 9%. Yet, at $100 per barrel, transport costs outweigh the impact of tariffs for all of America's trading partners. Hence, higher prices like $150 per barrel, tariff-equivalent to 11%, would have the same impact like import duties in the 1970s. A barrel at $200 would relate to a 15% tariff-equivalent.[226]

Accordingly, high oil prices could divert trade based on geographical proximity. [227] Over the next decade, more manufacturing activities are expected to come back to the U.S, as high oil prices makes it substantially more expensive to move things from China to the US.[228] Cost advantages in East-Asia could be more than offset by high oil prices. [229] Hence, manufactures looking for cheap labour halfway around the world, will more and more include transportation costs in their calculation. The key will be to find the cheapest work force within a reasonable shipping distance to the market, for instance, low-cost manufacturing supplying the US market is likely to move from China to Mexico. [230]

[224] European Commission: White Paper: Roadmap to a Single European Transport Area, 2011, p. 7
[225] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p.
[226] Rubin, J., Tal, B.: Will Soaring Transport Costs Reverse Globalization, 2008, p. 5
[227] Ibid, p. 6
[228] Smith, F.: FedEx CEO Fred Smith on… everything, 2012, p. 2
[229] Rubin, J., Tal, B.: Will Soaring Transport Costs Reverse Globalization, 2008, p. 5
[230] Ibid, p. 6

4.5 Airfreight

4.5.1 Impacts on Energy Use

Airfreight transportation is in particular affected by high oil prices. Since air transportation accounts for the highest energy consumption per unit, the cost structure of airlines is drastically impacted. 10 years ago, fuel costs for airlines accounted for 13% of their running costs; in 2011, this share is about 30%.[231]

Finding ways to reduce or replace the current oil consumption is difficult. Other ground transportation modes can either rely on other alternative energy sources like wind, hydro, nuclear and solar or flexible fuel car and bus engines for electricity as well as replacing diesel locomotives with electro-powered trains. Such a wide range of alternatives is not available for aircraft.[232]

Aircrafts face restricted fuel types for transportation purposes. Aircrafts demand a high energy density of fuels in order to overcome large distances, which make gaseous fuels or using electricity rather unlikely for implementation. [233] In short there is no foreseeable new technology to power flight beyond hydrocarbon fuels.

So, the only option which remains today is liquid hydrogen. Although hydrogen can be burned in aircraft turbine engine, it requires significant technical changes in designing a hydrogen-powered aircraft. Moreover, at the current stage, it is not possible to produce sufficient amounts to satisfy industry needs. However, research using nanotechnology is looking for ways to transport hydrogen in a safe and convenient way, but the prospects of commercialization remains unclear.[234]

Hence, biofuels, probably produced with algae, are the most likely resource to replace petroleum-based jet fuel. The technology has been proven, but breakthroughs are needed to produce the fuel on the necessary scale.[235]
Airliners and aircraft manufactures are highly interested in high quality and high energy-density aviation biofuels. The main concern of using biofuels is the question

[231] Deutsche Post AG: Delivering Tomorrow – Logistics 2050, A Scenario Study, 2011, p. 152
[232] Boeing Company: Response to the European Commission Communication on “A sustainable future for transport, p. 5
[233] International Energy Agency: Transport Energy and CO2, 2009, p. 39
[234] Air Transportation Action Group (ATAG): Beginner’s Guide to Aviation Biofuels, 2011, p. 7
[235] Smith, F.: Oil Scare Turns FedEx On To Energy Efficiency, p.2

of real sustainability and feedstock supply.[236] The main requirement to find ways to commercialization and scalability of sustainable aviation biofuels is to make sure R&D resources are aimed on aviation's requirements and sustainability.[237]

Apart from the technical side, is it currently not economical to use biofuels. Based on today's oil resp. kerosene prices, producing suitable biofuels for aircrafts is twice as expensive than current kerosene prices. Given today's high oil prices, a change to biofuels is likely to happen in the following three steps:

- First, governments will implement climate polices, which are adding cost to fossil fuels.
- Second, politics and economics are looking for ways to increase jet kerosene prices.
- Third, biofuel production is subject to economies of scale, thus prices are falling.[238]

Forecasts count up to 30% of jet fuel could be made of sustainable and commercially viable sources like biofuels by 2030.[239]

Apart from biofuels, fuel efficiency can also be improved by new airplanes. New planes from Boeing or Airbus are promising large increases in fuel efficiency. Taking into account the large improvements of fuel efficiency of about 70% over 40 years, future increases at a rate of 1 to 2% per year are expected.[240]

4.5.2 The Future Role of Airfreight

Airliners see oil prices and their availability as a basic threat to the future of the airline industry. [241] Many agencies see air transportation as the fastest growing transport mode of the future. Given normal circumstances, air transport generally grows faster than normal GDP, leading to a particular increase of aviation energy use.[242] Airbus even expects air transportation to become a complementary mode for door-to-door

[236] International Energy Agency: Transport Energy and CO2, 2009, p. 39
[237] Boeing Company: Response to the European Commission Communication, 2009, p. 3
[238] Air Transportation Action Group (ATAG): Powering the future of flight, 2011, p. 3
[239] Airbus S.A.S.: Airbus contribution to EC consultation, 2009, p.4
[240] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 266
[241] Ibid, p. 266
[242] International Energy Agency: Transport Energy and CO2, 2009, p. 38

services, representing an efficient alternative to highly congested ground transport systems.[243]

But as mentioned before, fuel accounts for a high share (about 15-30%) of operating expenses; all other cost functions are more or less fixed or predictable. Accordingly, almost only high oil prices are affecting shipping rates.[244] You can observe this in premium charges on tickets when oil prices are high or within the transport sector on various modes to pass the high oil prices on to the customer. In addition, the air transportation sector is highly competitive and the profit margins tend to be low.[245]

Especially non-time-sensitive bulk cargo shipments have a low profit margin, so a switch to Sea & Ocean or Rail transport will be likely a possibility in the future. High value shipments mostly transported in an express mode, may be less impacted.[246] Nevertheless, during the recession in 2008 with high oil prices, customers also switched to slower services even for high value shipments. In this case, savings from shipping costs were more important than a next-day delivery.

Taking into account these observations, air transportation could be significantly impaired by high oil prices.

In order to reduce the effects of high oil prices, the air transportation needs to focus on energy efficiency and intermodal solutions.

Consolidating flights and for preparing a fair playing field, a true liberalization of air transport throughout the world is required – this would be the ultimate goal.[247] Even the delays in creating a Single European Sky (SES) prevent a possible fuel saving of 12% per flight.[248]

243 Airbus S.A.S.: Airbus contribution to EC consultation, 2009, p.4
244 Strategic Aviation Special Interest Group: SASIG Response to EC consultation, 2009, p.1
245 Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 266
246 Ibid, p. 266
247 European Express Association (EEA): Contrubution to the consultation on future european transport policy, 2009, p. 2
248 Alliance for European Logistics (AEL): Comments on the communication from the commission on the future of the European transport policy, 2009, p. 7

Fuel efficiency can and will be reached by every new generation of aircraft. [249] But taking into account the lifecycle of an aircraft can easily exceed 30 years for normal travel (freight carriers have even longer lifecycles), fleet turnover takes place at a very slow pace.[250] But as mentioned in previous chapters, although fuel efficiency technologies remain unexploited, aerodynamic improvements, weight reduction and engine efficiency could have an overall impact leading to an aircraft twice as efficient in 2050 as today.

In addition, air traffic control could improve the overall fuel efficiency in air transport with savings between 5 and 10%. Summing up these potential savings, major investments in aircraft and aviation technologies may be cost-effective in the long run.[251]

Another chance to stay competitive and increase fuel efficiency is to link air transport with intermodal solutions. Key for an uptake of global transit solutions will be assuring integration between different modes of transport.[252]

To achieve integration, airport capacities need to be optimized or increased; also an upgraded infrastructure for handling other transport modes is required. High speed rail could absorb much medium distance traffic.[253]

Apart from the high oil prices, other factors are also influencing the future of air transport. Just an example for passenger aircraft, tele-presence or video-conferences will lead to less business class travel. [254]

However, the general problem for the airline industry is that dealing with planes is capital-intensive. Assuming enduring high oil prices and arising reduction in freight volumes from it, the airline industry may not be financially healthy enough to pay for commercial advances, which have fostered growth in the past.

[249] International Energy Agency: Transport Energy and CO2, 2009, p. 38
[250] Deutsche Post AG: Delivering Tomorrow, 2010, p. 117
[251] International Energy Agency: Transport Energy and CO2, 2009, p. 38
[252] Strategic Aviation Special Interest Group: SASIG Response to EC consultation, 2009, p.1
[253] European Commission: White Paper: Roadmap to a Single European Transport Area, 2011, p. 7
[254] Plattner, H.: Ich freue mich auf die Zukunft, in: manager magazin, 11, 2011, p. 140

Another big point which needs to be raised is the change in climate policies. Carbon emissions have risen drastically, requiring political solutions from governments. It is expected that the regulatory environment will become much more stringent over the coming years. There are two main options, both imposing additional costs on airlines:

- Cap-and-trade sets a specific reduction target with carbon credits becoming a tradable currency like the US-dollar or the Euro. The EU introduced the European Union Emissions Trading System (EU ETS) in January 2012. It is the first transport related concept which is heavily opposed and boycotted by nations outside the EU. The outcome remains unclear.
- Levy taxes on fossil fuels like kerosene to discourage their use, and encourage alternative energy sources. Many countries already use taxes on fossil fuels to support their environmental policies.

The major challenge for the success of these measures is providing for a level playing field:

- find the right tax balance between not preventing growth, but changing behaviour with a positive effect on sustainability.
- accomplishing measures on an international level, but due to the many parties involved, it is likely that binding regional regulations will be more common than global ones (like in the EU).[255]

The last point affecting the future of air transport is terrorism and security. [256] Security measures in the airline industry are leading to incremental costs (e.g. X-Ray), increased requirements for customer (which can move to other transport modes without these restrictions) and to delays in freight handling due to new rules and policies.

4.6 Railway

4.6.1 Impacts on Energy Use

Rail transport has the most efficient energy form of all transport modes and is based on two energy forms: diesel and electricity. Most of rail freight still relies on fuel, but in future chances are good to shift to much greater use of electricity through the electrification of lines. The impact on the environment of electric trains is generally

[255] Deutsche Post AG: Delivering Tomorrow, 2010, p. 135-136
[256] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 263

better than that of diesel trains, but depends on the applied diesel technology and the respective electricity mix.

The main difference lies in possibility to use sustainably generated electricity, which leads to a better environmental performance of electric trains than that of diesel trains. What needs to be considered is that the marginal environmental impact from electric energy will be determined in an integrated electricity market by the marginal supplier of electricity. It is difficult to determine from which source any use of electricity is coming from.[257]

In many countries, rail freight accounts only for small part of freight transport compared to road transport, thus the only option to increase energy efficiency is a shift from road to rail. As rail transport is so much more efficient than road transport, only fostering a modal shift can help. But increasing rail freight requires major investments both in rail infrastructure and in intermodal facilities to allow goods easily being taken on and off rail systems. This should be supported and stimulated by government interventions.[258]

4.6.2 The Future Role of Rail Transport

Rail transportation - as it is the most energy efficient and ca. three times more energy efficient than trucking - is probably the mode, which benefits substantially from higher oil prices.[259] On a global basis many of the current transportation modes will become unaffordable as fuel prices rise, including developed as well as developing countries. The best option will be a shift from energy intensive air and road transport to rail.[260]

But rail faced some drawbacks: Rail freight is sometimes seen as an unattractive mode and is, despite some initiatives improving the rail sector, far from developed to its maximum capacity. [261] Freight rail suffers from a quality problem and fails to deliver satisfactory reliability for cross-border services. This for instance a main

[257] Van Essen, H.: The Environmental Impacts of Increased International Road and Rail Freight Transport, 2008, p.23
[258] International Energy Agency: Transport Energy and CO2, 2009, p.269
[259] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 266
[260] Raina, Rajeswari S., Agricultural Trade after the Peak Oil, 2010, p. 22
[261] European Construction Industry Federation (FIEC): FIEC contribution to the EC Communication, 2009, p. 3

problem within the EU despite opening up the market in 2007 and prevents a larger use of rail freight.[262]

While some states have well functioning rail systems, there is a lack of quality systems in many other countries. In order to increase rail freight, a structural change needs to be initiated to provide a competitive structure for medium and long distance freight market shares. This must be accompanied by large-scale investments to upgrade the rail network capacity. [263] Another main requirement will be standardization for cargo in order to provide a seamless transition between all transport modes. [264]

A market which can offer this, is for instance in the US and Australia, where the rail freight sector represents ca. 40% of a market share in 2006, up from 29,5% in 1990.[265] The success is always linked to the level of service offered by the rail providers, but mainly to the range in distances and the fragmentation of the system.

Nevertheless, high oil prices will probably have an impact on long distance rail transportation, but depending on the geography and the already existing system. There will be likely a change to electrification of lines of strategic long distance corridors to reduce oil consumption.[266]

As mentioned above, the integration of air cargo with high-speed rail is a critical development, especially within the EU. [267] Some projects are still ongoing like the CAREX (Cargo Rail Express) project in France, linking destinations in European cities by high speed train overnight and thus leveraging rail infrastructure.[268] The EU enforces a complete high-speed rail network by 2050, providing a dense railway network in all EU member states mainly for medium-distances (over 300 km).[269]

[262] Alliance for European Logistics (AEL): Comments on the communication from the commission on the future of the European transport policy, 2009, p. 7
[263] European Commission: White Paper: Roadmap to a Single European Transport Area, 2011, p. 7
[264] European Intermodal Association (EIA): Public Consultation on the communication on a sustainable future of transport, 2009, p. 3
[265] Allianz pro Schiene e.V.: Stellungsnahme: Public Consultation – Future of Transport, 2009, p. 3
[266] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 266
[267] European Intermodal Assocation (EIA): Public Consultation on the communication on a sustainable future of transport, 2009, p. 2
[268] Ibid, p. 2
[269] European Commission: White Paper: Roadmap to a Single European Transport Area, 2011, p. 8

Another option is the introduction of dedicated priority rail freight corridors.[270] To give an example how the future of rail freight transport could look like, a German university in Bochum has developed a large format tube system, called CargoCap: The main idea is to transport freight, instead of using road, on driverless trolleys through underground tunnels directly to shopping malls, industrial and logistics parks. To achieve this, an 80 km ring tunnel must by built bypassing one of the highest volume highways and railway switches every two kilometers, bringing the freight to underground stops where needed. So far, high costs and delays in research prevented the project from implementation. Tubes have high capital, but low operational costs – given increasing oil prices and climate change policies, this might be the future.[271]

Since Rail is the most efficient mode, but particularly underdeveloped, Rail will gain more market share in the future. The change to Rail as a replacement for all other transport modes is more likely, the higher oil prices increase. But: no price tag – no change in behavior. [272] Government initiatives are required to enforce rail transport, either by subsidies and research or levy tax on fuels in transportation modes. Assuming the introduction of electrification on all railways, rail could become even “greener” than today, making it to the leading transport mode in sustainability. If it is decided to support Rail freight transport systems, Rail is in the best position to fulfill future requirements.

4.7 Road Transportation

4.7.1 Impacts on Energy Use

Road transportation accounts for the majority of oil consumption of all transport modes. And to be clear right from the start: So far, no groundbreaking, market-ready technologies are currently available to revolutionize the road transport sector.[273] It is assumed that internal combustion engines, in combination with presumably liquid or gaseous energy from renewable sources, will remain on the market in 2050.[274] According to forecasts the transport sector will still heavily rely on gasoline and

[270] Deutsche Post AG: Delivering Tomorrow, 2010, p. 117-118
[271] Deutsche Post AG: Delivering Tomorrow, 2010, p. 117-118
[272] UNIFE – the European Rail Industry: More rail = Less CO2, 2009, p. 27
[273] Deutsche Post AG: Delivering Tomorrow, p. 106
[274] AEGPL: Position Paper on the Future of Transport:, 2009, p 1

diesel, accounting for 80% of the fuel mix. Other energy forms are biofuels and CNG with a share of 12% respectively 5%.[275]

Nevertheless, there are many alternatives for road transportation for passengers and freight over short and medium distances like rail, public transit and cycling. [276] To give an indication for the freight sector, passengers car fuel per 100km is supposed to drop by 60% by 2030: in the US from 8.5 to 5.5 litres, in OECD countries, China and Japan from 7 to 4.5 litres. [277] For the freight sector, fuel efficiency of gasoline-powered light trucks is supposed to increase by 37%and for diesel light trucks by 50% by 2035.[278] Apart from alternatives fuels, this will also be supported by new materials used in future vehicles like ceramic, plastic, aluminium, composite materials, etc.[279]

With regard to alternative fuels, hybrid vehicles and biofuels are the most promising options. [280]

Electricity is also an option, but still in the development phase. This would decrease the use of oil, but increase the use of electricity. To give an indication: for Germany, a transition to electric propulsion would increase the overall electricity demand by 3%.[281] But an all-electric pickup and delivery van is expected to operate at 75% less per-mile cost than an internal combustion engine variant.[282]

Hybrid vehicles for freight transport are particularly suitable for smaller trucks (7.5 – 12 tons) in urban traffic with many stops and low average daily mileage. Compared to line haul traffic or heavy-duty trucks with energy savings of only 2-6%, the use in dense areas is expected to save energy in the range of 15-25%.
New development like the plug-in hybrid vehicle can be charged from the grid, so there is no need to return to fuel. This could reduce fuel consumption by another ca. 50% in comparison to hybrid vehicles. In order to achieve the best results, plug-in

[275] World Energy Council: Global Transport Scenarios 2050, 2011, p. 53
[276] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p.262
[277] British Petroleum: BP Energy Outlook 2030, 2011, p. 30
[278] Deutsche Post AG: Delivering Tomorrow, p. 113
[279] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 263
[280] Pirker, F.: Effizientere Verkehrssysteme, in: Profil, Ausgabe Nr. 26, 2011, p. 92
[281] Ibid, p. 92
[282] Smith, F.: Oil Scare Turns FedEx On To Energy Efficiency, 2012, p.2

hybrid vehicle should only be used in urban areas with high stop density, also reducing the noise level in cities. [283]

For larger trucks, an alternative energy answer could be liquid compressed gas (LNG), which could lead to savings of about 40% compared with diesel at 2012 prices.[284]

With regard to biofuels, the variable costs are more or less comparable to conventional engines. Biofuels projects have been already initiated by governments with specific targets, but proving biofuels on a global level needs the required infrastructure and is therefore currently not really an option.[285]

4.7.2 The Future Role of Road Transport

It is assumed that road transport will remain essential to freight mobility in the future.[286] But the road transport perspective will be widened: While transport has been seen as the relocation of freight from A to B, today it needs to be integrated into the greater understanding of individual transport modes and supply chains.[287]

The provide the same level of road transport with regard to higher oil prices, road transport will be subject to major changes: integration to intermodal modes and an increase in energy efficiency.

In Europe, road freight volumes are supposed to shift to rail and Sea & Ocean transport by 30% by 2030 and 50% by 2050 for medium-distances over 300 km. [288] Intermodality is essential for the future of road transport, for instance the so-called Mega-Trucks or Ecocombis, although providing economic advantages, do not fit with a policy of intermodality.[289]

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[283] Deutsche Post AG: Delivering Tomorrow, 2010, p. 107-108
[284] Smith, F.: Oil Scare Turns FedEx On To Energy Efficiency, 2012 p.2
[285] Deutsche Post AG: Delivering Tomorrow, p. 111
[286] European Construction Industry Federation (FIEC): FIEC contribution to the EC Communication, 2009, p. 3
[287] Danish Transport and Logistics Association (DTL) : Comments on the European Commission's Communication on a Sustainable Future for Transport, 2009, p. 7
[288] European Commission: White Paper: Roadmap to a Single European Transport Area, 2011, p. 8
[289] European Intermodal Association (EIA): Public Consultation on the communication on a sustainable future of transport, 2009, p. 4

To foster intermodality, government and truck companies need to collaborate, for instance when freight shifts from road to rail, large investments are required. As mentioned before, only a small part of freight is currently transported by rail, but with high oil prices, rail is the best option to save energy due its energy efficiency.[290]

Also, further liberalization could help: In the EU, up to 30% of trucks are driving empty due to road cabotage restrictions and inefficiencies.[291] Another point is to save fuel is eco-driving training, which reduces fuel consumption by 20%, but because drivers are not used to it, the average saving is about 7%.[292]

What will also affect the future of transport is the combination of innovative solutions and simple road infrastructure improvements. Today, but even in the future, congestion, traffic safety and the environmental impacts are determining road transport systems. The solutions are Intelligent Transport Systems (ITS).[293]

Since freight shipments with a distance below 300 km will mainly be driven by trucks, intelligent transport systems are the cheapest way to enhance the overall performance of transport systems. Although ITS are invisible to the public, they enforce changes or upgrades in road infrastructure.[294] In addition, information technologies like vehicle control, location, navigation and toll collection included in cars can improve road transport efficiency. [295]

Taking all the above into account, high oil prices will lead to several changes in the road transportation sector. Increasing oil prices could trigger a sequence of events:

In the beginning, higher costs would be absorbed by savings in other operating costs or by declining profits. Since price elasticities are very low, transport providers will show a remarkable resilience. [296] Although transport providers recognize a long-term

[290] International Energy Agency: Transport Energy and CO2, 2009, p. 37-38
[291] Alliance for European Logistics (AEL): Comments on the communication from the commission on the future of the European transport policy, 2009, p. 7
[292] Deutsche Post AG: Delivering Tomorrow, p. 115
[293] European Union Road Federation (ERF): Strategic Road Infrastructure Priorities – Beyond 2010, 2009, p. 3
[294] Royal Automobile Club Foundation: Communication Document 279/4 - , A sustainable future for transport, 2009, p. 7
[295] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 263
[296] Ibid, p. 266

issue, nothing fast will happen to change their fleet.[297] For private vehicles, the next step is to use carpooling or public transport. A decline in sales of SUVs and people moving from suburban areas into the cities is also expected. Road transport will be forced to find solutions, triggering the move to other transport modes or passing the incremental costs onto the customers.[298]

[297] Yergin, D.: The Quest, 2011, p. 667
[298] Rodrique, J.-P., Comtois, C., Slack, B.: The Geography of Transport System, 2009, p. 266

5 Summary and Conclusions

The thesis at hand aimed to answer the research questions formulated in the introduction:

- What role does oil play in today's economy and who are the actors shaping the oil industry?
- What is the past and future oil supply and demand status and what is the Peak Oil Theory?
- To what extent is globalization driven by the interdependencies of global trade, transport and oil?
- What are the impacts of high oil prices on energy security, geopolitical shifts and economies?
- How will the future of transportation be shaped by high oil prices and alternative energy forms, especially in the four major segments Sea&Ocean, Airfreight, Rail and Road transportation?

Therefore, this chapter aims to summarize the contributions made towards answering the research questions and draw conclusions based on these findings.

Oil has a special role in today's economy. Almost everything in the industrial world depends on cheap oil, and due to its unique properties, it is almost impossible to find a proper substitute.
Also, the demand for oil is steadily rising. In 2010, 87 million barrels per day were consumed. The rise of the emerging markets like China and India, will lead to even more oil consumption, driven by the energy hunger of the non-OECD countries. Whereas in the past OECD countries accounted for more than 50% of the oil consumption, it is expected that in next few years the non-OECD countries will overtake the OECD countries. The daily oil consumption will rise to over 110 million barrels per day in 2030, with China as the world's largest oil consumer.
The supply of oil is mainly coming from the "Oil Triangle" of Saudi Arabia, Kuwait, Iraq and Iran, overall the Middle East was the biggest exporter with a share of 35% of worldwide exports in 2010. The consuming countries are dependent on these producing countries.

The main oil producing countries are represented in the OPEC, the Organization of the Petroleum Exporting Countries. OPEC's purpose is the stabilization of oil prices, but as a "cartel" representing the oil exporting countries, it also has a vital interests to protect the member's interests, e.g. by high prices.
The world's oil reserves account for 1383 thousand million barrels, which were sufficient to meet ca. 46 years of global production based on today's consumption. 77% of all oil reserves are located in OPEC countries, making them one of the most influential organizations worldwide with regard to oil.
The main pain point with regard to oil reserves is that reserve accounting lacks transparency and standardization. Especially OPEC countries follow a so-called production quota system, which allows production based on the member's share of total OPEC reserves. That means, the higher the national reserves, the higher the production quota and thus the country's export profit. Introduced in 1985, it resulted in an inexplicable jump of reported oil reserves of more than 300 billion barrels, although no new discoveries or advances in technology were reported. Many analysts doubt the official reporting and believe that the newly reported oil was only paper reserves and politically motivated.
When it comes to oil prices, the basic price principle does not apply to oil. The physical sides of demand and supply, financial factors and various reasons such as oil shocks are building a complex model for oil prices. Forecasting oil prices is hard, particularly as oil is inelastic to price changes, also for the transport sector. Overall, the numbers are very small and show a low price responsiveness to oil consumption: the long-term price elasticity for OECD and non-OECD countries is at -0.072, which means a 10% permanent increase in oil prices reduces oil demand by only about 0.72% after 20 years. To put this in perspective: for a long time, $100 per barrel was considered a threshold that would limit demand, but evidence suggests that higher oil prices had limited impact on the average growth of demand.

Given the above mentioned points and the fact that oil is a fossil definite resource and only available to a limited extent, the question is when will oil run out or reach the maximum in production? The Peak Oil Theory refers to this question, arguing that world oil output is currently near the highest level it will ever reach, that about half of the world's resources have been produced, and that the point of imminent decline has already begun, or is soon to set in. The founder of this theory was King Hubbert.

He created a graph of oil production, which takes the shape of a bell curve and predicted the oil production in the US would peak between 1965 and 1970. U.S. oil production peaked in 1971 indeed, his model is now used for global reserves. Critics point out that Hubbert didn’t take two key elements into account: technological progress and price. Neither economics nor new technologies have been considered, but applying new technologies is dramatically improving the recovery rate.

So, the ultimate question is: How much oil can be produced at a meaningful rate in the immediate and foreseeable future? A growing gap is expected: rising demand, more difficult access to the remaining oil fields and little or no new reserves contribute to that gap. Moreover, some countries and companies admitted to have overestimated their own resources.
Given the unreliable data, various industry interests and assumption, a date for Peak Oil is still an uncertainty.

Oil plays a significant role in today’s economy, especially when it comes to global trade and transportation. In the last 50 years, transport demand grew considerably. Trade enables countries to specialize in specific products and services, economies of scale and other related comparative advantages. The interchange of goods between countries is an inevitable aspect of today’s global economy and the relationships with regard to flows of capital, goods, information and services increased interdependencies. This is what is called globalization today and trade has been both a primary cause and effect of it. It is one of the key drivers for more prosperity and increased living standards around the world.
But critics say that globalization has also a negative effect on people. Some see globalization one of driving reasons behind the Iraq war and other crises, especially the financial crisis. For instance, bailout money favors only banks and corporations. It is a “race to the bottom”, forcing developing countries to adopt poorer labor regulations and hence contributes to global inequality. They claim that free trade promised fairer conditions for the poor, but globalization has not taken the interests of the developing world into account.

The increase in trade was only possible because of a reduction in transportation costs: in 1960, overall costs of logistics accounted for 15% of the total value of export; today transport costs are down to less than 1% in some areas.
But transport is heavily dependent on oil. Oil is the dominant fuel for transportation with a share of 98-99%. Hence, without oil there is virtually no mobility and accordingly, transportation is the most exposed part of the economy to oil.
Transport is a fundamental component of today's global economy. There are four major segments shaping the transport industry:

Sea&Ocean transport: accounting for than 90% of global trade. Its main advantage is its capacity, the economies of scale and low energy demand, transforming it into the cheapest per unit of all transport modes.

Airfreight transport: accounts for only 2% of global trade volume, but for 40% of the global trade value. Airfreight is the main contributor in supporting "just-in-time" production and plays an integral role where fast delivery prevails over cost issues.

Rail transport: its primary asset is to haul large quantities of goods over long distances at a reasonable speed and more efficient than road transportation. It is also considered as a green system, but the main obstacle of integration is the lack of interoperability due to different gauges within the networks.

Road Transport: dominates the market for short distance trips due to many significant advantages: low capital costs, high relative speed and the flexibility of route choice, providing door to door services.

So, how are the areas of trade, transportation and our today's life affected by the future of oil development? In theory, the impacts range from a best case scenario over the business as usual to the worst case scenario. In the best case scenario, oil production plateaus and technology progress finds ways to replace oil with equally rich and abundant alternative energy sources. The business as usual case assumes that a conversion of oil is not possible and a large number of states are not in a position to make the required investments in time to change their oil behaviour. This leads to an increase in transportation costs, food prices as well as the cost of living and impacts the global economy, which could lead to global recession. The worst case scenario includes the 'tipping point', which means the global system does not reacts reasonably, but in a chaotic way. This results in a chain reaction: rising oil prices reduce consumption, leading to recessions. Governments face increasing social spending due to rising unemployment and declining tax revenues. Due to the shrinking economy, companies make hardly any profit and financial markets – the backbone of the global economy – collapse.

High oil prices or Peak Oil will have a significant impact on transportation, trade and our today's life. An increase in oil prices would affect the interdependent infrastructures of the global economy, especially in industrialized countries.

When Peak Oil will occur is hard to predict, since various industry interests, unreliable forecasts and politically motivated assessments have different approaches and outcomes. It is difficult to imagine what will happen, if one of the most important energy sources will run out or becomes unaffordable. In the end, it is not important to know when exactly Peak Oil occurs, but that Peak Oil will occur and that we will face higher prices over a longer period of time.

High Oil prices will not only transform economic and social structures, but will also impact energy security thinking. Only one oil market exists and this market is complex. Let there be a disruption in one part of the world, and the effects will reverberate throughout the market. Energy security is not really about being independent, but being "not vulnerable". But today's energy systems are vulnerable in many forms. Consuming countries rely on oil from a much smaller number of producing countries, most of them politically unstable. Moreover, the security of supply routes – or even the entire supply chain – has become another important challenge to cope with. A surge in piracy is adding a further dimension to security concerns, and there are many important sea routes like the Strait of Hormuz. The upheavals across North Africa and the Middle East have transformed the politics of the region upended the least part of the geostrategic balance that has underpinned stability. This means greater uncertainty and risks of crises, which translates into a increased risk premium in the price of oil.

Furthermore, there are many other risks “above ground”. It’s about the relations among nations and other institutions. The influence of international organizations increases, so will the weight of national states. The power of nations will shift from oil importing countries to oil exporting countries. Oil exporting countries are likely to use their power to increase their political influence. Since oil importing countries are dependent on oil and have to fight for the limited remaining resources, values and moral aspects will be playing a decreasing role in oil negotiations.

Higher prices will also impact the transportation industry and trigger notable changes in usage, modes, networks and supply chain management. Looking at the different transport modes, each mode is characterized by different technologies. This affects the way how the different transport modes become more energy efficient, which alternative energy forms can be used and what kind of role they play in a more integrated intermodal future.

Logically, high oil prices are likely to be tackled in two ways: innovations and energy efficiency. With regard to innovations, this includes alternative energy forms, renewables and new technologies, each applied in a different way according to the respective transport mode. Energy efficiency is also one of the key priorities for the growing world economy. Technologies, which were not available in earlier decades are now at hand. To increase the energy efficiency, innovations and new knowledge are essential, which requires investments. But without increasing R&D to develop applying science, the world will pay a much larger price.
Hence, policies related to energy can have a major impact on the timeliness of investment. Policies are supposed to encourage investment and technological advance, also in order to foster research of alternative energies. In transportation, energy efficiency is already evident and also biofuels are likely to have a growing presence, but to gain market share, they need to reach the second generation.

The Sea&Ocean segment is less affected than road or airfreight, but high oil prices question if off-shore production is still a better solution. Over the next decade, for instance, it is expected to have more manufacturing activities come back to the U.S. When oil prices were at $20 a barrel, a container had costs of $3.000. Today, costs

are ca. $8.000 and with an oil price of $200, costs explode to ca. $15.000, offsetting the cost advantages in East-Asia.
Nevertheless, seaports will play an increased role, especially for food and agriculture transport from developing countries, gaining market share from airfreight business. This will lead to an increase in fuel use for container shipping, some project an up to eight-fold increase until 2050. To increase energy efficiency, the most effective way is to reduce speed. Some studies argue that the difference between actual fuel consumption and optimum fuel consumption is up to 26%. Fuel cell technology is the most likely option for propulsion systems, and redesigning the hull in terms of hydrodynamic could increase energy efficiency by 15-20%.

Airfreight transportation is particularly affected by high oil prices. Since a substitute for oil is difficult to find in an airfreight context, oil prices are a basic threat to the future of the airline industry. Moreover, the air transportation sector is highly competitive and especially non-time-sensitive bulk cargo shipments have a low profit margin. A switch to Sea&Ocean or Rail transport will be likely in the future.
Although there is no foreseeable new technology to power planes beyond hydrocarbon fuels, options are liquid hydrogen and biofuels. Both energy forms need breakthroughs in order to produce them on a necessary scale. Based on today's oil prices, producing suitable biofuels for aircraft is twice as expensive as current kerosene prices.
Moreover, airfreight business will be heavily impacted by climate policies, which are adding cost to fossil fuels. The major challenge will be to find the right tax balance between not preventing growth and to change behavior with a positive effect on sustainability. This will lead to increasing jet kerosene prices, but favors the production of biofuels.
And still, air transport is not liberalized, e.g. creating a Single European Sky (SES) would lead to fuel savings of 12% per flight. Furthermore, air traffic control could improve overall energy efficiency by 5-10% and new airplanes are also expected to increase efficiency due to improvements in aerodynamics: Over the last 40 years, fuel efficiency improved by about 70%, thus future increases at a rate of 1 to 2% per year are expected.

Rail transportation is probably the mode, which benefits the most from higher oil prices. Most rail freight still relies on fuel, but the future chances are good for a shift towards a much greater use of electricity through the electrification of lines.
In many countries, rail accounts only for a small part of freight transport, since it suffers from a quality problem and fails to deliver satisfactory reliability for cross-border services. But as rail transport is so much more efficient than road transport, only fostering a model shift can help. This requires large-scale investments both in rail infrastructure and in intermodal facilities.
Two other options are the introduction of dedicated rail freight corridors and the introduction of high-speed rail. High speed rail is likely to be combined with air freight transport, e.g. the CAREX project in France, linking destinations in European cities by high speed trains overnight.
Since Rail transport is the most efficient mode, but particularly underdeveloped, it will gain more market share in the future. Assuming the introduction of electrification on all railways, rail could become even "greener" than today. If governments or companies decide to support rail freight systems, rail is in the best position to fulfill future requirements.

Road transportation accounts for the majority of oil consumption of all transport modes. In the future, road transport will be integrated to intermodal modes and supply chains. Forecasts for Europe predict a shift of market share from Road to Rail and Sea&Ocean by 30% by 2030 and 50% by 2050 for medium-distances over 300 km. Road transport should remain the last-mile provider, since intermodality is essential for the future of transport. To increase energy efficiency, liberalization and Intelligent Transport Systems (ITS) could be helpful. In Europe, up to 30% of trucks drive empty due to road cabotage restrictions and inefficiencies. Intelligent Transport Systems can help to avoid congestion and contribute to fuel efficiency.
But for road transport, high oil prices would be absorbed by savings in other operating costs, declining profits or passing the incremental costs on to the customers. And since price elasticities are very low, transport providers will show a remarkable resilience, so changes to the fleets will not happen fast.
Although no groundbreaking technology is currently available, hybrid vehicles, biofuels and electricity are only some of the options to replace or reduce oil consumption. Hybrid vehicles for freight transport are particularly suitable for smaller

trucks in an urban traffic environment, with energy savings up to 25%. Electricity is also an option, but still in its development phase. An all-electric pickup and delivery van is expected to operate at 75% less-per-mile cost than an internal combustion engine variant. Biofuel costs are already more or less comparable to conventional engines, but the required infrastructure is currently not available on a global level.

The consequence of the above mentioned facts is a shift towards more energy efficient modes as well as higher levels of integration between the modes to create multiplying effects in energy efficiency. While globalization was favored by cheap and efficient transport systems, the new relationships between transport and energy are likely to restructure the global structure of production and distribution towards intermodality.

But if this is enough to reduce the impacts of higher oil prices, remains unclear. The growth in world energy demand will be very large in the coming decades and even today supply might be inadequate to keep up with rising demand. By 2030, the overall energy consumption may be 35-40% higher than today. Churchill's famous dictum about supply: "variety and variety alone" still sounds powerful. Instead of oil resources diversification, there is a need for a diversification among energy sources. The longer-term question is whether the era of cheap energy is over and how the world will adapt and adjust to new energy sources. Some potential substitutes and new sources are a lot less efficient, in the sense that it requires significant amounts of energy to simply produce it.

The challenges of meeting rising energy needs are truly daunting, considering the scale. Meeting them requires, among other things, the responsible and efficient use of energy, sound judgment, consistent investment, long-term thinking and the thoughtful integration of environmental considerations into energy strategies. However, there is no guarantee that innovations will be implemented on time in order to make a real difference. There is no guarantee that the investment at the scale needed will be made in a timely way or that government policies will be wisely implemented. Things can go seriously wrong, with dire consequences. Just as the industrial revolution was built on coal, the post-second-world-war economy was built on cheap oil. There will surely be a significant impact if it has gone for good.

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